

# U.S. FISH AND WILDLIFE SERVICE SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

## Scientific Name:

*Calidris canutus ssp. rufa*

## Common Name:

Red Knot

## Lead region:

Region 5 (Northeast Region)

## Information current as of:

05/16/2011

## Status/Action

☐ Funding provided for a proposed rule. Assessment not updated.

☐ Species Assessment - determined species did not meet the definition of the endangered or threatened under the Act and, therefore, was not elevated to the Candidate status.

☐ New Candidate

☒ Continuing Candidate

☐ Candidate Removal

☐ Taxon is more abundant or widespread than previously believed or not subject

☐ Taxon not subject to the degree of threats sufficient to warrant issuance of

☐ Range is no longer a U.S. territory

☐ Insufficient information exists on biological vulnerability and threats to s

☐ Taxon mistakenly included in past notice of review

☐ Taxon does not meet the definition of "species"

☐ Taxon believed to be extinct

☐ Conservation efforts have removed or reduced threats

## Petition Information

☐ Non-Petitioned

☒ Petitioned - Date petition received: 08/10/2004

90-Day Positive:09/12/2006

12 Month Positive:09/12/2006

Did the Petition request a reclassification? **No**

**For Petitioned Candidate species:**

Is the listing warranted(if yes, see summary threats below) **Yes**

To Date, has publication of the proposal to list been precluded by other higher priority listing?  
**Yes**

Explanation of why precluded:

Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for this species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The Progress on Revising the Lists section of the current CNOR (<http://endangered.fws.gov/>) provides information on listing actions taken during the last 12 months.

**Historical States/Territories/Countries of Occurrence:**

- **States/US Territories:** Connecticut, Delaware, Florida, Georgia, Louisiana, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Texas, Virginia
- **US Counties:** County information not available
- **Countries:** Argentina, Barbados, Brazil, Canada, Chile, Jamaica, Trinidad and Tobago

**Current States/Counties/Territories/Countries of Occurrence:**

- **States/US Territories:** Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Texas, Virginia
- **US Counties:** Bay, FL, Broward, FL, Charlotte, FL, Collier, FL, Escambia, FL, Franklin, FL, Gulf, FL, Indian River, FL, Jefferson, FL, Lee, FL, Martin, FL, Miami-Dade, FL, Monroe, FL, Okaloosa, FL, Palm Beach, FL, Santa Rosa, FL, Sarasota, FL, St. Lucie, FL, Wakulla, FL, Walton, FL, Androscoggin, ME, Cumberland, ME, Hancock, ME, Knox, ME, Lincoln, ME, Penobscot, ME, Sagadahoc, ME, Washington, ME, York, ME, Atlantic, NJ, Cape May, NJ, Cumberland, NJ, Ocean, NJ, Beaufort, SC, Charleston, SC, Colleton, SC, Georgetown, SC, Horry, SC, Accomack, VA, Northampton, VA, Virginia Beach, VA
- **Countries:** Argentina, Brazil, Canada, Chile

**Land Ownership:**

In the United States approximately 25 percent of sites are federally owned; 40 percent are State-owned; 10 percent are municipal or County-owned; and 25 percent are privately owned. Land ownership of the principal wintering areas in South America is approximately 75 percent Federal or other public land and 25 percent privately owned. Of the known arctic breeding sites identified in Canada, approximately 50 percent are on Federal lands, 35 percent are privately owned, and ownership of remaining areas is unknown (Niles et al.

2007, pp. 172-178). No ownership information is available for migration and secondary wintering areas in Mexico, the Caribbean, Central America, and northern South America.

### **Lead Region Contact:**

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## **Biological Information**

### **Species Description:**

The red knot (*Calidris canutus*) is a medium-sized shorebird about 9 to 11 inches (in) (23 to 28 centimeters) in length with a proportionately small head, small eyes, short neck, and short legs. The black bill tapers steadily from a relatively thick base to a relatively fine tip; bill length is not much longer than head length. Legs are typically dark gray to black, but sometimes greenish in juveniles or older birds in non-breeding plumage (feathers) (Harrington 2001, p.2). During the breeding season, the plumage of the red knot is distinctive and easily recognizable. The face, breast, and upper belly are a rich rufous-red, while the feathers of the lower belly and under the tail region are light-colored with dark flecks. Upperparts are dark brown with white and rufous feather edges; outer primary feathers are dark brown to black (Davis 1983, p. 372; Harrington 2001, p. 2). Females are similar to males, though rufous colors are typically less intense, with more buff or light gray on dorsal parts (Niles et al. 2007, p. 14). Non-breeding plumage is dusky gray above and whitish below. Juveniles resemble non-breeding adults, but the feathers of the scapulars (shoulders) and wing coverts (small feathers covering base of larger feathers) are edged with white and have narrow, dark subterminal bands, giving the upperparts a scalloped appearance (Davis 1983, p. 372). Body mass varies seasonally, with lowest mean mass during early winter (125 grams (g)) and highest mean values during spring (205 g) and fall (172 g) migration (Harrington 2001, p. 12).

*Calidris c. rufa* is the palest subspecies. The chin, throat, breast, flanks, and belly are characteristically brick red or salmon red, sometimes with a few scattered light feathers mixed in. The undertail is white, often including scattered brick-red or salmon-red feathers, marked with dark, terminal chevrons (V-shaped markings) laterally. The crown (top of head) and nape (back of neck) are streaked with black and gray and/or salmon; prominent superciliary (above eye) stripe is brick red or salmon red, auricular (ear) region and lores (area between eyes and base of beak) are colored as in the crown, but with finer streaks. Back-feathers and scapulars have dark brown-black centers edged with faded salmon. Scapulars and tertials (innermost flight feathers) are unevenly colored, with broad, dark, irregular-shaped centers, widely edged in notched patterns to variable degrees, some with faded salmon and others with bright salmon-red color. The lower back and upper tail-coverts are barred black and white, with scattered rufous. Primary feathers (main flight feathers on the outer half of wing) are dark brown to black, secondaries (feathers along trailing edge of inner segment of wing) and remiges (longest feathers on wing) are gray. Younger males tend to be less brightly colored dorsally (on the back) and have greater numbers of light feathers scattered among ventral (on the belly) feathering. The underwing is duller than in other *Calidris* subspecies (Tomkovich 1992, p. 20; Harrington 2001, p. 4).

### **Taxonomy:**

The red knot is classified in the Class Aves, Order Charadriiformes, Suborder Charadrii, Family Scolopacidae, Subfamily Scolopacinae (American Ornithologists Union (AOU) 2005). Six subspecies of

*Calidris canutus* are recognized, each with distinctive morphological traits (i.e., body size and plumage characteristics), migration routes, and annual cycles. Six separate breeding areas are known to host different populations, all of which are now recognized as subspecies (Piersma and Davidson 1992, p. 191; Tomkovich 1992, pp. 20-22; Piersma and Baker 2000, p. 109; Tomkovich 2001, pp. 259-262; Beuhler and Baker 2005, pp. 498-499).

Three of the six subspecies occur in North America: *C. c. islandica*, *C. c. roselaari*, and *C. c. rufa*. The North American lineage was established about 12,000 years ago as glaciers retreated, allowing establishment of new migratory pathways. As the ice sheets retreated further eastward across the High Arctic of Canada, the ancestral population was further fragmented within the last 5,500 years, into three breeding populations, corresponding today into *C. c. islandica*, *C. c. roselaari*, and *C. c. rufa* (COSEWIC 2007, p. 9). The subspecies *C. c. islandica* breeds in the northeastern high Canadian Arctic and Greenland, migrates through Iceland, and winters in western Europe. Subspecies *C. c. roselaari* is thought to breed in northwest Alaska and Wrangel Island, Russia and winters along the west coasts of North, Central, and South America and possibly northeastern South America. *C. c. rufa* breeds in the central Canadian Arctic and migrates primarily along the Atlantic coast of North America (Piersma and Davidson 1992, p. 191; Harrington 2001, p. 4; U.S. Fish and Wildlife Service (USFWS or Service) 2003, p. 15). Most *C. c. rufa* individuals winter along the coasts of South America, with the largest number found along the Chilean and Argentine shorelines of Tierra del Fuego (Morrison and Ross 1989, pp. 37-40; Harrington 2001, p. 4; USFWS 2003, p. 16), with lesser numbers wintering in the vicinity of Maranhão, Brazil and the southeastern United States along the Atlantic and Gulf coasts (Morrison et al. 2006, pp. 76-77). Knots wintering in the southeastern United States have been grouped with *C. c. roselaari* based on differences in migration timing and molt patterns from *C. c. rufa* wintering in Tierra del Fuego (Buehler and Baker, 2005, p. 500). Although some overlap of *C. c. rufa* and birds thought to be *C. c. roselaari* occurs in the southeastern United States during the non-breeding season and some birds thought to be *C. c. roselaari* may migrate through the Delaware Bay (Harrington 2001, pp. 5-6; USFWS 2003, p. 16; Buehler and Baker 2005, p. 499), *C. c. rufa* and *C. c. roselaari* are believed to occupy separate breeding areas (Piersma and Davidson 1992, p. 191; Harrington 2001, pp. 4-5; USFWS 2003, p. 15; COSEWIC 2007, p. 9).

Buehler and Baker (2005, pp. 499-509) examined genetic variation in red knot populations. These analyses found patterns of genetic distinctiveness that complement the subdivision of red knots into the six aforementioned subspecies. The genetic distance between *C. c. rufa* and *C. c. roselaari* is small, but similar to the genetic distance between *C. c. rogersi* (southeast Australia and New Zealand) and *C. c. canutus* (Eurasia) (COSEWIC 2007, p. 7).

Pursuant to the definitions in Section 3 of the Endangered Species Act of 1973 (ESA), “the term species includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.” Based on the information described above, the Service accepts the Buehler and Baker taxonomy and finds the red knot subspecies *rufa* is a valid taxon which qualifies as a listable entity under the ESA. For the purpose of this form, further references to the red knot pertain to subspecies *C. c. rufa*.

## **Habitat/Life History:**

Each year red knots make one of the longest distance migrations known in the animal kingdom, traveling approximately 30,000 kilometers (km (18,641 miles (mi))) annually between wintering grounds in southern South America and breeding areas within the Canadian Arctic. Although small populations overwinter in Florida and northern Brazil, most red knots winter in southern South America along the coast of Patagonia, from approximately San Antonio Oeste, Argentina, southward to the eastern coast of Tierra del Fuego in Chile and Argentina (Harrington 2001, p. 6; Baker et al. 2004, p. 876; Morrison et al. 2004, p. 62). In South American wintering areas, red knots are found principally in intertidal marine habitats, especially near coastal inlets, estuaries, and bays, or along restinga formations (an intertidal shelf of densely-packed dirt blown by

strong, offshore winds) (Harrington 2001, p. 9). Small numbers of red knots are also found overwintering in coastal habitats as far north as the mid Atlantic United States (Niles 2009, p. 1).

In wintering and migration habitats, red knots commonly forage on bivalves, gastropods, and crustaceans (Harrington 2001, pp. 9-11). In the southeastern United States, red knots forage along sandy beaches, tidal mudflats, salt marshes, and peat banks. In Florida, the birds also use mangrove and brackish lagoons. Along the Texas coast, red knots forage on beaches, oyster reefs, and exposed bay bottoms and roost on high sand flats, reefs, and other sites protected from high tides (B. Ortego, pers. comm. 2008). Niles et al. (2009, p. 1) found that Coquina clams (*Donax variabilis*), a frequent and often important food resource for red knots, were common along Gulf beaches and in some places occurred abundantly.

During migration, red knots undertake long flights that may span thousands of kilometers without stopping. At some stages of migration, high proportions of entire populations may use a single migration staging site (stop along the journey where birds congregate) to prepare for long flights. Migrating red knots are principally found in marine and estuarine (partially enclosed tidal area where fresh and salt water mixes) habitats (Harrington 2001, pp. 8-9). During the spring migration, red knots stop over for a period of approximately two to three weeks along the Atlantic coast of the United States to rebuild energy reserves needed to complete the journey to the Arctic and arrive on the breeding grounds in good condition (Harrington 1996, pp. 70-78; Baker et al. 2004, p. 876).

Within Virginia, red knots are found on barrier island beaches and marsh islands along the Atlantic Ocean. The island chain is backed by extensive shallow lagoons with open water, mudflats, peat banks, and tidal marsh (Cohen et al. 2009, p. 940). Red knots have also been observed to a much lesser extent along beaches in the Chesapeake Bay (B. Watts pers. comm. 2009). In coastal Virginia, red knots feed within peat banks on blue mussels (*Mytilus edulis*) and on Coquina clams and crustaceans on sandy beaches. Horseshoe crab (*Limulus polyphemus*) eggs are not considered a major food resource for red knots in Virginia (Truitt et al. 2001, p. 12; B. Watts pers. comm. 2009; Cohen et al. 2010a, pp. 355, 358-359).

Within the Delaware Bay of Delaware and New Jersey, red knots are found primarily on beaches of sand or peat at the mouths of tidal creeks and along the edge of tidal marshes dominated by salt marsh cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*S. patens*) (Niles et al. 2007, pp. 44-45; (Cohen et al. 2009, p. 940). Red knots also can be found along New Jersey's Atlantic coastal barrier islands during spring and fall migration, especially within the southern portion of the State. These barrier islands are characterized by sandy beaches and adjacent intertidal flats, punctuated by tidal inlets that allow the ocean to flush into the marsh and back bay lagoons (Cohen et al. 2010b, p. 656). On New Jersey's Atlantic coast, horseshoe crab eggs are present, but not in great abundance. Instead, red knots have been observed foraging in areas where mussel spat is abundant, such as intertidal flats (Sitters 2001, p. 4; Cohen et al. 2010b, p. 659).

In wintering and migration habitats, red knots commonly forage on bivalves, gastropods, and crustaceans (Harrington 2001, pp. 9-11). An exception occurs each May when the majority of red knots departing South America arrive within the Delaware Bay of Delaware and New Jersey to feed on eggs of horseshoe crabs (Wander and Dunne 1982, p. 62; Harrington 1996, p. 73; Harrington 2001, p. 11). Piersma et al. (1993, pp. 560-561) suggest this divergence from other foods preferred by the red knot may be due to the bird's reduced ability to digest hard-shelled prey items as a result of physiological changes in the bird's digestive system following the sustained fasting that occurs during the flight from South to North America.

Red knots and other shorebirds that are long distance migrants must take advantage of seasonally abundant food resources at intermediate stopovers, such as the horseshoe crab eggs in Delaware Bay, to build up fat reserves for the next long distance non-stop flight (Clark et al. 1993, p. 694). The timing of the arrival of red knots and other migratory shorebirds within the Delaware Bay typically coincides with the annual peak of the horseshoe crab spawning period (Clark et al. 1993, p. 694; Harrington 1996, pp. 76-77; Harrington 2001, p.

11). While there can be variation from year to year, in general, the temporal pattern has been for horseshoe crab spawning to be low in early May, peak in late May or early June, and drop by late June (Smith and Michels 2006, p. 487).

Harrington (1996, p. 73) stated that no single stopover area is more important for the red knot than the Delaware Bay because the nutritive yield of the Bay is so high. Although a single horseshoe crab egg contains an insignificant amount of energy, Harrington (1996, p. 73) found that eggs “cover the beach in such astronomical profusion that the bird can eat enough in a mere two weeks to double its weight” and estimated that an individual red knot would consume almost 135,000 eggs during the Delaware Bay stopover. In a more recent study Haramis et al. (2007, p. 370) found that red knots in captive feeding trials consumed up to 24,000 horseshoe crab eggs per day. Although the birds were released before completing mass gain, it was projected that the birds would have increased egg consumption to achieve a weight gain of 6+ g per day as they approached a 180 + g condition. Red knots require approximately 5,000 horseshoe crab eggs per gram of body mass gained (Haramis et al. 2007, p. 373). Therefore, near the end of the stopover period, red knots would need to consume approximately 30,000 or more horseshoe crab eggs per day to achieve a 6+ g per day weight gain.

Stable isotope diet tracking and captive feeding trials by Haramis et al. (2007, p. 373) establish horseshoe crab eggs as a unique and likely critical resource to migratory shorebirds along the east coast of the United States. Haramis et al. (2007, p. 373) based the value of horseshoe crab eggs to red knots and other shorebirds on the predictable abundance in Delaware Bay, rapid digestion and assimilation, demonstrated importance to rapid fattening during the migratory stopover, and selected preference in the diet by the birds themselves. Further, Haramis et al. (2007, p. 373) failed to identify alternative food sources in Delaware Bay with comparable prey quality (i.e., the combined abundance and digestibility of horseshoe crab eggs). Horseshoe crab eggs are likely a good source of fatty acids that are the known primary fuel for migratory flight. Bivalve prey is less optimal for rapid fattening of shorebirds because of the high protein-to-calorie ratio that tends to minimize fat storage. Birds fatten more quickly on low protein-to high calorie diets either by assimilating fat directly, in the case of fat-rich diets, or by *de novo* (from the beginning; afresh) synthesis of fatty acids in the liver, in the case of high carbohydrate diets (Haramis et al. 2007, pp. 373-374). By contrast, red knots in Virginia appear to be able to adequately refuel during their stopover there, even though horseshoe crab eggs are not present in appreciable numbers. Instead, red knots selectively forage in areas where donax clams are abundantly available. For a red knot arriving at an emaciated 100 g, a weight gain of 5 g/day would be sufficient for the bird to reach 180 g within 16 days, the approximate length of time a bird arriving in Virginia in mid-May would be expected to stay (Cohen et al. 2010a, p. 362.)

Based on an average fat-free mass of 130 g late in the Delaware Bay stopover period, Baker et al. (2004, p. 876) determined that red knots need to build fat reserves and reach a departure mass of at least 180 to 200 g (threshold departure mass) just to cover the energetic costs of the flight to the breeding grounds and to survive an initial few days of snow cover. The approximate doubling of body mass, from arrival at 90 to 120 g to departure at 180 to 220 g, is achieved annually if conditions are favorable (Baker et al. 2004, p. 876). Individual red knots can store fat and protein at two to three times the annual average rate when horseshoe crab eggs are superabundant. Consequently, even late-arriving migrants should be able to reach these departure masses during their short stay. Research results indicate this weight gain is crucial to sustain the birds on their nonstop flight from the Delaware Bay, and for survival and successful reproduction on arctic breeding grounds (Baker et al. 2004, p. 876). A female red knot radio-tagged in May 1999, in Delaware Bay and recaptured incubating 4 eggs on the nest 6 weeks later in Canada had used up 60 g of reserves, demonstrating the importance of large scale weight gain during the stopover (Baker et al. 2001, p. 6)

Baker et al. (2004, pp. 878-881) found that from 1997 to 2002 an increasing proportion of red knots leaving the Delaware Bay failed to achieve threshold departure masses. The decline in threshold departure mass was attributed to later arrival in the Bay and food shortages associated with commercial harvesting of horseshoe crabs. This reduced nutrient storage, especially in late-arriving birds, appears to have had severe fitness consequences for adult survival and recruitment of young in 2000 to 2002. From 1997 to 2002, known

survivors in Delaware Bay were heavier at initial capture than birds never seen again. Annual survival declined from an average of 84.6 percent in the migration years of 1994/1995 through 1997/1998 to 56.4 percent in the migration years of 1997/1998 through 2000/2001 (Baker et al. 2004, pp. 878-879). Between May 2000 and May 2001 annual survival of adults decreased by 37 percent and the number of second year birds in wintering flocks declined by 47 percent (Baker et al. 2004, p. 875).

Baker et al. (2004, pp. 875-882) analyzed 1997 to 2002 data from wintering populations in Tierra del Fuego and Patagonia and migrant red knots in the Delaware Bay to model annual survival of red knots. Assuming that adult survival in the future would average the pre-2000 level of 84.6 percent and a juvenile survival rate of half that of adults for 10 years from the year 2000, Baker et al. (2004, p. 879) predicted that the red knot population would remain stable at roughly 70,000 birds through 2010. However, applying the 1997/1998 through 2000/2001 adult survival rate of 56.4 percent and juvenile survival rate of half that of adults, Baker et al. (2004, p. 879) predicted that the population would decline to extremely low numbers (approaching zero) by 2010.

Using more recent information on individually tagged red knots, mark-recapture models were developed to estimate annual survival of Delaware Bay red knots based on mass at the end of the migratory stopover. The models focused on evaluating three research hypotheses: 1) heavy birds have a higher probability of annual survival than light birds, 2) arctic weather conditions upon arrival influence red knot annual survival, 3) horseshoe crab spawning abundance positively affects red knot weight transition probabilities during the Delaware Bay stopover (ASMFC 2009a, p. 18). The probability of red knots transitioning from a light weight state to a heavy state was positively related to estimated female crab abundance on spawning beaches in Delaware Bay (ASMFC 2009a, p. 23). Averaged (1997-2008) mean annual survival rate of heavy birds was approximately 0.92 and light birds was approximately 0.91. The largest differences in survival between these groups seem to occur in specific years. For instance, the 1998-1999 survival rate was 0.86 for heavy birds and only 0.79 for light birds. During most other years the survival rates were similar and high, although light bird survival was estimated to be lower than that for heavy birds in 6 of the 11 years of data analyzed (ASMFC 2009a, p. 20). The effect of weight on survival was not as strong as predicted by previous analyses (Baker et al. 2004, p. 879; ASMFC 2009a, p. 23). While it had been predicted that red knots would have lower survival rates in years of high snow cover, modeling showed a positive correlation between survival and Arctic snow depth. Survival of both heavy and light weight red knots was highest in years with greatest snow depth and lowest in years with little snow (ASMFC 2009a, p. 21).

Unknown numbers of non-breeding red knots remain south of breeding grounds during the breeding season. Records of non-breeding knots, usually individuals or small groups, have been reported during the breeding season in Brazil, the Caribbean, and along the Atlantic coast of the United States (Harrington 2001, p. 3; Niles et al. 2007, p. 105). Little information is available about these non-breeding red knots.

On Arctic breeding areas, red knots generally nest in dry, slightly elevated tundra locations, often on windswept slopes with little vegetation. Breeding areas are located inland, but close to arctic coasts. Nests may be scraped into patches of a specific plant, mountain avens (*Dryas octopetala*), or in low spreading vegetation on hummocky ground containing lichens, leaves, and moss. On Southhampton Island, nests were located in exposed areas of glacial/shattered rocks and mudboils and most were located in proximity to suitable wetland foraging areas (Harrington 2001, p. 8; Niles et al. 2007, p. 30).

On the breeding grounds, the red knot's diet consists mostly of terrestrial invertebrates, though early in the season, before insects and other macroinvertebrates are active and accessible, red knots will eat grass shoots, seeds, and other vegetable matter (Harrington 2001, p. 11).

The oldest red knot recorded world-wide was estimated to be 25 years old when recaptured; the oldest recorded red knot of the rufa subspecies was 16 years old when recaptured. Although these records indicate that the potential lifespan of a red knot is considerable, the average life span is much less. Annual adult survival in a stable population has been estimated at about 80 percent, and survival of juveniles in the wild is

about 40 percent. Therefore, very few red knots live for more than about seven years (Niles et al. 2007, p. 33).

The breeding chronology of *C. c. rufa* is poorly known. Flocks sometimes arrive at breeding latitudes before snow-free ground is available in breeding habitats. Upon arrival or as soon as favorable conditions exist, males and females occupy breeding habitat and territorial displays begin. Pair bonds form soon after and remain intact until shortly after the eggs hatch. Red knots lay only one clutch (group of eggs) per season, and, as far as is known, do not lay a replacement clutch if the first is lost. The usual clutch size is four eggs, though three-egg clutches have been recorded. No information is available regarding hatching success or chick survival rates. Young are precocial, leaving the nest within 24 hours of hatching and foraging for themselves. Although there is conflicting information, typically the female departs soon after the chicks hatch and only the male parent tends the brood until the chicks fledge (Harrington 2001, p. 20; Niles et al. 2007, pp. 28, 31-32). Adults migrate before juveniles (Harrington 2001, p. 6).

A major red knot staging area was recently located in the Mingan Islands Archipelago on the North shore of the St. Lawrence Gulf in Southern Quebec, Canada. Since 2006, intensive field work has been conducted documenting the importance of this site to southbound migrants from July until late October. Analysis of resightings of marked red knots by Alan Baker of the Royal Ontario Museum indicated that at least 7,200 red knots transited through the archipelago in 2008 (Y. Aubry pers. comm. 2010). Foraging areas consist of limestone flats with an abundant invertebrate fauna, dominated by high numbers of small periwinkles (*Littorina* spp.) and beds of tiny blue mussels. These sites are similar in habitat structure to red knot foraging areas within Argentina. Another fall staging site is the Magdalen Islands, which also form a small archipelago located in the middle of the St. Lawrence Gulf. Although red knot numbers are more modest at this site, noticeable flocks of juveniles have been observed in the recent years (2007-2009) (Y. Aubry pers. comm. 2010).

Other major staging areas for red knots during the fall migration in Canada are along sandy beaches and tidal mudflats in James Bay and tidal mudflats and salt marshes in the northern Bay of Fundy. During the fall migration within the United States, red knots are found along sandy beaches, tidal mudflats, and salt marshes (Niles et al. 2007, pp. 41, 64).

## **Historical Range/Distribution:**

The range of *C. c. rufa* during migration extends along the Atlantic and Gulf of Mexico coasts of North, Central, and South America, from the Canadian arctic to the southernmost extent of South America. With the exception of a few key wintering areas in South America and the spring migratory stopover site in Delaware Bay, little comparative information is available regarding the historical versus current distribution of the subspecies throughout its range.

Red knot breeding occurs within the central Canadian high arctic and has been recorded from Victoria Island southeastward to Southhampton Island, the Coats and Mansel Islands in northern Hudson Bay, and the east coast of Canada and islands within Foxe Basin. Details of historic or current distribution of red knots within the breeding range are poorly known. Little historic or current information is available for the extensive areas between Southhampton Island / Foxe Basin and southern Victoria Island (Morrison and Harrington 1992, pp. 72-73). Hellmayr and Conover (1948, p. 167) describe the historic known Canadian breeding area as northern Ellesmere Land south to southeastern Victoria Islands and Melville Peninsula.

In the late 1990s and early 2000s, additional information on breeding areas was obtained when 265 red knots were fitted with radio transmitters as the birds passed through the Delaware Bay on their way to breeding areas. During subsequent aerial searches of the known and potential breeding range, a total of 20 red knots were relocated, documenting additional breeding areas within Canada's King William Island, Boothia Peninsula, coast of Committee Bay, Melville Peninsula, southern coast of Baffin Island, and Prince Charles



Island, and confirming continued breeding at Southampton, Coats, and Mansel Islands (Niles et al. 2007, pp. 18-20). The eastern and western extent of the breeding range remains unclear.

Southward migration from arctic breeding areas begins in mid-July (Harrington 2001, p. 6). The northernmost staging areas are along the west coasts of James Bay and Hudson Bay in Canada (Morrison and Harrington 1992, p. 74). In 2006, a major staging area for red knots was documented along the Mingan Islands Archipelago on the north shore of the St. Lawrence Gulf and more modest southbound staging also occurring in the Magdalen Islands, a small archipelago located in the middle of the St. Lawrence Gulf. (Y. Aubry pers. comm. 2010). In the Canadian Maritime Provinces, adult red knot numbers peak in late July to early August with maximum numbers of juveniles appearing in late August to mid-September. On the northeastern United States coast, southward migrating red knots are distributed from Cape Cod Bay and the Chesapeake Bay with adults moving through beginning in late July, peaking in mid-August, and departing by September. In the mid to late 1970s, 60 to 90 percent of southerly migrating red knots were observed in Massachusetts and New Jersey; the relative importance of sites within these States varied from year-to-year. Migrant juveniles begin to appear along the Atlantic coastal United States in mid-August, occurring in much lower numbers and scattered over a much wider area than adults (Morrison and Harrington 1992, p. 75). Numbers of red knot adults and juveniles are generally decreasing in the northeastern United States by mid-August while increasing in the mid-Atlantic States, and moving to the southeastern and Gulf coast States throughout September and October (Morrison and Harrington 1992, p. 74; Harrington 2001, p. 6).

Red Knots of the *C. c. rufa* subspecies winter in four distinct coastal areas of the Western Hemisphere: the southeastern United States (mainly Florida and Georgia, with smaller numbers in South Carolina); the Gulf of Mexico coast of Texas; Maranhão in northern Brazil; and Tierra del Fuego (mainly Bahía Lomas in Chile and Bahía San Sebastián and Río Grande in Argentina with smaller numbers northwards along the coast of Patagonia) (Niles et al. 2008a, p. 17).

Of the red knots remaining in the southeastern United States to overwinter, the largest concentrations are found along the southwestern coast of Florida (Niles 2009, pp. 3-6), but, in some years, small numbers of red knots can be found in winter as far north as the mid -Atlantic States. In southwestern Florida, birds start arriving in early August with highest use occurring from early October through March. Few red knots are seen in Florida between mid-May and late July (Niles 2009, p. 10).

For red knots wintering in South America, most make landfall along the northern coast of South America after departing the United States. The birds move south along the coasts of Guyana, Suriname, and French Guiana, but do not build up in appreciable numbers (Spaans 1978, p. 72; B. Harrington pers. comm. 2006). Although a small population of red knots is believed to overwinter in northern Brazil, historically, the largest wintering concentrations have been found in South America along the coast of Patagonia, from approximately San Antonio Oeste, Argentina southward to the eastern coast of Tierra del Fuego in Chile and Argentina (Morrison and Ross 1989, pp. 37-40; Harrington 2001, p. 6; Baker et al. 2004, p. 876; Morrison et al. 2004, p. 62). The birds are present in the South America wintering areas from November through February (Morrison and Harrington 1992, p. 76).

It is unknown whether there is segregation of juvenile and adult red knots on the wintering grounds. The proportion of juvenile birds in catches of red knots within both the Tierra del Fuego and Florida wintering areas from 2002 to 2007 was less than 6 percent (A. Dey pers. comm. 2008). Whether this number is an actual reflection of annual recruitment or merely a subset of juveniles is not known (M. Peck pers. comm. 2008). The number of juveniles captured during November 2008 banding efforts in Chile was greater than in recent years (L. Niles pers. comm. 2009). In addition, a flock of 500 knots, assumed to be juveniles, was observed at Bahía Lomas in May 2009 (Niles et al. 2010, p. 2). In winter 2008/2009, Niles (2009, pp. 9-10) found the percentage of juvenile red knots peaked in January (13 to 15 percent) as compared to catches made in November (3 to 6 percent) and February (0 percent). This indicates suggests that juveniles may winter separately from adults or may occur in other habitats not used by adults (Niles 2009, pp. 9-10).

In coordinated counts of red knots conducted during the third week in May along the United States east coast from Florida to Delaware Bay, more red knots were observed in 2008 to 2010 than could be accounted for at known wintering sites. This suggests that red knots are using wintering sites that remain undiscovered (Dey and Niles 2011, p. 9). Range and distribution during the fall and spring migration and winter in Mexico and Central America is not well known (B. Harrington pers. comm. 2006). Historic accounts by Hellmayr and Conover (1948, p. 167) recorded red knots during migration in the West Indies only from Jamaica, Barbados, and Trinidad. The red knot is now considered a rare or vagrant visitor to the Caribbean islands with the exception of Barbados, where it occurs regularly. Generally rare in the West Indies in September and October during the southbound migration, red knots occur there even less frequently while migrating northward in March and April (Raffaele et al. 1998, p. 277).

During the spring migration, red knots begin moving northward along the Atlantic coast of South America in late February or March (Baker et al. 2001, p. 5). Migration continues along the Argentine coast to Uruguay, Brazil, and northern South America. The northward migration is very rapid, with only brief stopovers of up to a week in northern South America. Red knots pass along the Atlantic coast of the United States from the middle to the end of May (NJDEP 2007, pp. 14-15). Some historical records of flocks of up to 12,000 red knots have been reported along the southeastern Atlantic seaboard north to Virginia during the spring migration. Based on observations throughout the 1980s, Harrington (1996, pp. 64-65) thought such records of large red knot numbers were the exception rather than the rule and that when knots were observed at areas outside of the Delaware Bay it was never for more than a brief feeding and rest stop. However, more recent surveys have shown that birds in Virginia stopover about as long as birds in Delaware Bay and that Virginia serves as an important alternative and independent stopover site (B. Watts pers. comm. 2009; Cohen et al. 2009 pp. 941-944; Cohen et al. 2010a, p. 356).

Recent coordinated aerial surveys for red knots by shorebird biologists along the Atlantic Flyway have found flocks of over 2,000 in coastal Georgia and more than 8,000 in coastal Virginia during the third week of May (NJDEP 2010, p. 26) and over 4,000 still remaining in Virginia at the end of May (NJDEP 2007, pp. 14-15).

Information collected periodically since 1995, suggests that coastal Virginia hosts a substantial number of red knots during the spring stopover. The coastal marshes of Virginia are extensive, with much of the area inaccessible except by boat. Prior to the mid 1990s, the Virginia islands received little attention from shorebird scientists and available estimates of use by migrant shorebirds were relatively poor (Watts and Truitt 2000, p. 33). Therefore, it is unclear whether red knot use of the area as a spring stopover is a new circumstance or if red knots had been historically present but undetected. Aerial surveys were conducted at low tide on six occasions each year from the last week of April to the first week of June on approximately 111 km (69 mi) of open beach along the Virginia barrier islands. Peak counts of red knots were 7,710 in 1995 and 8,955 in 1996 (Watts and Truitt 2000, p. 35; Truitt et al. 2001, p. 12). Comparing these peak counts to those from aerial surveys conducted in Delaware Bay in the same two years, Virginia hosted approximately 20 percent and 46 percent, respectively, as many red knots as did Delaware Bay. Counts of birds using the Virginia barrier island beaches should be considered minimum counts because the adjacent lagoon / tidal marsh areas were not included in the aerial surveys. Densities of shorebirds were estimated to be several times higher in the areas not surveyed (Watts and Truitt 2000, p. 38).

Beginning in 2006, coordinated aerial red knot surveys have been conducted from Florida to Delaware Bay during two consecutive days within the period of May 20 to 24 each year. This period is thought to represent the peak of the red knot migration. Virginia has supported a third or more of the total red knots observed in the mid-Atlantic Region during 4 of the 5 surveys conducted to date (NJDEP 2010, p. 26). Resightings of red knots in coastal Virginia have documented use by birds banded in Argentina, Brazil, Canada, Chile, and the United States (including birds originally banded within Delaware Bay (Smith et al 2008, pp. 22-29). Further, resightings of banded birds have documented movement of red knots between coastal Virginia and Delaware Bay, between years and within years. This suggests that the Delaware Bay stopover is not an entirely closed system as had been previously thought (B. Watts pers. comm. 2009; Cohen et al. 2009, p. 943). Radio telemetry studies conducted in 2006 and 2007 in Virginia and Delaware Bay suggest that the majority of red

knots stopping over in Virginia refueled there and proceeded directly to their next migration stop (possibly the Arctic breeding grounds) without passing through the Delaware Bay. A small number of Virginia-radiotagged red knots relocated to the Delaware Bay area just before the expected time of migration to the Arctic, but it is not believed that these birds used Delaware Bay as their primary refueling stop (Cohen et al. 2009, p. 943).

Two spring migration cohorts of red knots are now thought to exist: short-distance migrants that make smaller hops along the Atlantic coast, and those that make longer-distance flights directly to the Delaware Bay (Niles et al. 2008a, p. 36). Stable isotope analyses of feathers collected in Delaware Bay indicate that red knots from wintering areas in both South America and the southeastern United States stop within the Bay during spring migration (Atkinson et al. 2005, p. 744). Feather proteins formed during molt assimilate an isotopic signature that is determined by a bird's diet. Once grown, the feather is metabolically inert and forms an isotopic record that reflects that of the environment in which the bird molted. This isotopic record remains valid until the next molt (Atkinson et al. 2005, p. 739). Feather analysis of red knots found along the southern Atlantic coast of New Jersey show this area is more heavily represented by birds from the southeastern United States. This difference suggests that red knots using the Delaware Bay / New Jersey Atlantic coast region during the spring stopover may partially segregate, at least in some years (Cohen et al. 2010b, p. 656, 660).

Historically, the Delaware Bay region of Delaware and New Jersey has supported the largest known spring migration concentration of red knots (Harrington 1996, pp. 77; Baker et al. 2001, p. 5; NJDEP 2007, p. 15). Approximately 90 percent of the entire population of *C. c. rufa* can be present in the Delaware Bay in a single day (Cornell Lab of Ornithology 2005, p. 1). Peak counts of approximately 95,000 red knots were recorded during Bay-wide aerial surveys conducted in 1982 and 1989. Since 2003, peak counts within Delaware Bay have been substantially lower, with counts of less than 17,000 red knots recorded (NJDEP 2005, p. 1; Clark and Porter 2006, p. 1; 2007, p. 1; 2008, p. 1; NJDEP 2010, p. 26).

Red knots depart the Delaware Bay in a mass exodus occurring during the last few days of May or first few days of June (Morrison and Harrington 1992, p. 77; Harrington 2001, p. 7). The northward migration route from the Delaware Bay bears inland with large numbers of knots observed in James Bay, Canada, on the day following a mass departure from the Delaware Bay. In some years, large concentrations of red knots have been observed at locations around Lake Ontario; these likely represent weather-induced stops. Knots pass rapidly through southern James Bay in spring, stopping only briefly (less than one day) to feed in coastal marshes before resuming their flight to the breeding grounds (Morrison and Harrington 1992, p. 79).

In Florida, the ranges of *C. c. rufa* and *C. c. roselaari* are believed to overlap somewhat during migration and winter (Morrison and Harrington, 1992, p. 78; Harrington 2001, pp. 4-7; USFWS 2003, p. 15; Buehler and Baker 2005, p. 499). Red knots migrating along the Pacific Coast and through the interior of North America are generally considered to be *C. c. roselaari* (Harrington 2001, p. 4-7; Morrison et al. 2001, p. 33; USFWS 2003, p. 15).

## **Current Range Distribution:**

See section above. Current and historical range are discussed together.

## **Population Estimates/Status:**

Assessing the population size of a wide-ranging migratory species such as the red knot is difficult. Counts on the expansive Arctic breeding areas are not feasible. Morrison et al. (2001, pp. 14-45) compiled published and unpublished counts of shorebirds by season and region to generate a coarse flyway population estimate for North American breeding shorebirds. Populations were determined by summing the maximum counts at various sites within a region. Using this method, the *C. c. rufa* population was estimated at approximately

170,000 birds for the period of the late 1980s to early 1990s (Morrison et al. 2001, p. 33). However, the authors included the central flyway population of approximately 20,000 red knots as *C. c. rufa* (Morrison et al. 2001, p. 34). While the origins of the central flyway red knots are uncertain, these birds are generally thought to be *C. c. roselaari* (Morrison et al. 2001, p. 34, USFWS 2003, p. 95; Morrison et al. 2006, p. 76). Morrison et al. (2001, p. 34) estimated the eastern North American flyway population of *C. c. rufa* for the period of the late 1980s to early 1990s at approximately 150,000 birds, and noted that based on information through 1999, the population could be substantially lower.

Counts of wintering areas are particularly useful in estimating red knot populations and trends as the birds generally remain within a given wintering area for a longer period of time compared to the areas used in migration. This eliminates errors associated with turnover or double-counting that can occur during migration counts. The population of red knots wintering in southern South America during the late 1980s was estimated to be in the range of 100,000 to 150,000 birds. These estimates were derived from aerial survey data and resightings of banded birds (Morrison and Harrington 1992, p. 78). Principal wintering areas, located in the Tierra del Fuego region of Chile and Argentina, supported approximately 78 to 98 percent of the red knots observed during winter aerial surveys in southern South America in those years where additional portions of the Patagonian coast were surveyed. In an updated estimate of North American shorebird populations, the red knot population wintering in southern South America was estimated to be as low as 20,000 birds (Morrison et al. 2006, p. 71).

Currently, the most reliable information available to monitor population trends is the raw data estimates from winter aerial survey counts. Recent surveys for the red knot within known wintering areas on the coasts of Patagonia and Tierra del Fuego, where the largest wintering concentrations of red knots occur, show a substantial decline in the number of wintering birds observed and a contraction of wintering range. Total red knots observed in these wintering areas in 2003, were estimated at only 30,000 birds as compared to an estimated 67,500 birds observed in the mid-1980s (Morrison et al. 2004, p. 65). In the mid-1980s wintering red knots could be found along 1,600 km (994 mi) of the Atlantic coast of South America from Tierra del Fuego to Río Colorado in northern Patagonia (Morrison et al. 2004, p. 62). Surveys of a comparable area in 2003 and 2004, showed that knots have nearly disappeared from previously-used wintering sites outside of Tierra del Fuego on the Patagonian coast of Argentina; numbers counted fell from over 14,300 birds in the 1985 survey to only 560 in 2003 and 790 in 2004 (Niles et al. 2007, p. 80). The population thus appears to have contracted to the core sites, leaving few birds at the Patagonian “peripheral” sites (COSEWIC 2007, p. 11)

In 2005 through 2011, additional aerial surveys were conducted of Bahía Lomas and other portions of Tierra del Fuego and southern Patagonia that comprise the principal red knot wintering areas in Chile and Argentina. A somewhat different geographic distribution of birds was noted in 2006 (K. Ross pers. comm. 2007), indicating that birds may shift distribution within principal wintering areas in a given year. Counts of red knots within principal areas showed an all time low of only 14,800 in 2008, much lower in comparison to other years for which red knot aerial count data of the same area are available: 53,232 birds in 1985; 51,255 in 2000; 34,355 in 2001; 27,242 in 2002; 29,915 in 2003; 30,778 in 2004; 17,653 in 2005; 17,211 in 2006; and 17,360 in 2007 (K. Ross pers. comm. 2006; 2007; Niles et al. 2007, pp. 78-80; R.I.G. Morrison pers. comm. 2008). The red knot population within the principal wintering areas in Chile and Argentina, declined by nearly 75 percent from 1985 to 2007, and by an additional 15 percent from 2007 to 2008.

Red knots within the Tierra del Fuego wintering area increased by 20 percent over 2008 to 17,780 birds in 2009, similar to numbers found during 2005-2007 (R.I.G. Morrison pers. comm. 2009). The number of juveniles captured during November 2008 banding efforts in Chile was greater than in recent years (L. Niles pers. comm. 2009). In addition, a flock of 500 knots, assumed to be juveniles, was observed at Bahía Lomas in May 2009 (Niles et al. 2010, p. 2). Presence of an increased number of juveniles and an overall increase in wintering red knots likely indicates a good breeding season in the Arctic in summer 2008 (L. Niles pers. comm. 2009; R.I.G. Morrison pers. comm. 2009). It is not clear whether good productivity in 2008 is the sole reason for the increased wintering population in Tierra del Fuego in 2009. Higher productivity in 2008 should

have led to even higher counts in Tierra del Fuego in 2010 as there is evidence that many juveniles do not go there until their second winter. However, the 2010 winter count in Tierra del Fuego decreased to 16,260 red knots, indicating that there may have been low survival of juveniles or adults from 2009 to 2010 (Niles et al. 2010, p. 2).

In 2011, shorebird biologists from Environment Canada conducting aerial surveys reported a substantial decrease in red knots in Tierra del Fuego from 16,260 in 2010 to only 9,850 in 2011 (R.I.G. Morrison pers. comm. 2011). Most of the loss occurred on Bahía Lomas, Chile, where red knot numbers fell from 15,450 in 2010 to a historic low of 9,450 birds in 2011 (Dey and Niles 2011, p. 1). Ground counts in the Bahía Lomas area one month later (February 2011) by biologists from Chile and the United States verified the decrease. About 1,500 more red knots were found during February ground counts in Bahía Lomas than had been observed during the January aerial count, but the ground counts confirmed that a substantial decline in wintering red knots had occurred in the area. Only about 11,200 birds were observed in 2011 (about 4,250 fewer red knots than in 2010) (L. Niles pers. comm. 2011; Dey and Niles 2011, p. 1).

The decrease in Tierra del Fuego follows six years of stable numbers averaging just under 16,500 knots with the exception of winter 2007/2008 when only 14,800 red knots were counted. The subsequent increase in the following year may suggest that the birds were present in 2007/2008 and were missed by the surveyors or were wintering in another location (Dey and Niles 2011, p. 1). Both aerial and ground counts in Río Grande, Argentina, also showed a decline in 2010/2011 to only 400 red knots as compared to previous counts of 1,600 birds in 2008/2009 and 750 birds in 2009/2010 (Dey and Niles 2011, p. 1).

In summary, numbers of red knot observed during wintering counts in Tierra del Fuego since 2005 remain very low as compared to wintering numbers of over 50,000 red knots observed in Tierra del Fuego in 1985 and 2000. As noted above, these areas in southern South America are not the only locations used by wintering red knots, so the survey results are best interpreted as indications of population trends rather than estimates of the total population of red knots.

Baker et al. (2005, p. 12) found 7,570 red knots wintering in Maranhão, Brazil during an aerial census conducted in 2005. This number was a decline of only approximately 575 red knots reported for the same area in the mid-1980s by Morrison and Ross (1989, p. 40; Baker et al. 2005, pp. 12), however birds were of very low weight (Baker et al. 2005, pp. 15). From preliminary analysis of band sightings at Maranhão, Baker et al. (2005, p. 13) concluded that the wintering flocks at Maranhão are a separate population from that in Tierra del Fuego. Morrison et al. (2006, p. 76) also considers the red knots wintering in northern Brazil to be a separate biogeographical population from those wintering in southern South America. In winter 2006/2007 only 3,000 red knots were observed in Maranhão despite intensified survey efforts. However, the shoreline within the Maranhão area is complex and highly fragmented, making accurate counts more difficult (Niles et al. 2008b, pp. 6-7). There has been no known survey of the red knot population wintering in Maranhão area since the 2006/2007 count.

In 2011, shorebird biologists from Environment Canada and the New Jersey Audubon Society conducted aerial counts in Suriname, French Guiana, and from Belem to São Luís in northern Brazil. This was the first count of wintering red knots in northern Brazil since the original Shorebird Atlas counts conducted in 1982 to 1985 (Dey and Niles 2011, p. 2). The Atlas documented 8,326 red knots in 1985 (Morrison and Ross 1989, p. 183). Counts of red knots wintering in northern Brazil declined to only 3,980 birds in 2011 (Dey and Niles 2011, p. 2).

Morrison et al. (2006, p. 76) estimated the Florida / southeastern United States red knot wintering population in 2005 at about 7,500 individuals based on aerial survey data. During January 23 to February 19, 2006, 150 sites in Florida, Georgia, South Carolina, North Carolina, and Virginia were surveyed for red knots in the course of a U.S. Geological Survey piping plover (*Charadrius melodus*) survey, which is conducted every 5 years. A total of 4,569 red knots were counted in the five states, with the majority, 3,020 birds, found in Florida (Niles et al. 2006, p. 89).

A portion of the southwestern coast of Florida has been surveyed annually since winter 2005/2006. Approximately 2,500 red knots were observed during the winter of 2005/2006 along a portion of the west coast of Florida with subsequent counts of 1,200 birds in winter 2006/2007, 550 birds in 2007/2008, 1,532 birds in 2008/2009 and 1,378 birds in 2009/2010 (Niles et al. 2008, p. 7; Niles 2009, p. 2; Niles et al. 2010, p. 2). The Florida wintering area was not surveyed by air in 2011, and ground counts were not performed simultaneously. Therefore, the current status of the wintering population in Florida is unknown (Dey and Niles 2011, p. 2).

Records compiled by Skagen et al. (1999) reported flocks of up to 2,838 and 2,500 red knots along the Gulf of Mexico coast in Texas and Louisiana, respectively. Morrison et al. (2006, p. 76) estimated about 300 red knots wintering along the Texas coast. Only an average of 43 red knots were reported in Texas during Christmas Bird Counts conducted in the 5-year period from 2003-2007, but these low numbers may be attributed to poor public access to shorebird habitats (B. Ortego pers. comm. 2008). A flock of 700 red knots was observed on North Padre Island, Texas in Fall 2009 Niles et al. (2009, p. 1).

Records of migrating red knots have been collected at many sites along the Atlantic coast of the United States. Not all migration areas are well surveyed, and considerable turnover of individuals occurs as birds migrate through an area. Consequently, using counts of migrating red knots as a basis for population estimates may lead to inaccuracies due to errors associated with turnover or double-counting. However, counts made at a specific location are good indicators of usage trends for that area and may reflect trends in the overall population of the knot.

Peak counts of red knots along the Virginia coast were 7,710 in 1995 and 8,955 in 1996 (Truitt et al. 2001, p. 12). Since 2006, coordinated aerial surveys for red knots have been conducted during two consecutive days within the period of May 20 to 24 each year. Counts of red knots in coastal Virginia were 5,783 in 2006, 5,939 in 2007 (Cohen et al. 2009, p. 943), 7,802 in 2008, 3,261 in 2009, and 8,214 in 2010 (NJDEP 2010, p. 26). The consistency of documented counts of thousands of red knots indicate that coastal Virginia may be a more important migratory stopover area for red knot than was previously known. There is evidence of within year movements where some red knots use Virginia as a primary refueling stopover and later also stop in Delaware Bay or the New Jersey Atlantic coast prior to departing the United States. Radio telemetry studies have shown that small numbers of birds from Delaware Bay may also move south to Virginia and then back to the Bay (Cohen et al. 2009, pp. 942-943).

The Delaware Bay of Delaware and New Jersey, long thought to be the red knot's principal North American spring migratory stopover area, has shown declines in red knot numbers similar to that observed in wintering areas in South America. While the peak count of red knots observed at Delaware Bay is often described as the population estimate for the Bay, raw data from aerial surveys are not useful in estimating total populations of shorebirds in the Bay (USFWS 2003, p. 31). The aerial survey technique does not account for immigration and emigration at sites between surveys. Therefore, estimating population size during migration requires that raw count data be corrected for the error introduced by turnover between counts. In a study by Cohen et al. (2009, p. 939, 942), red knot spring passage populations in both Delaware Bay and Virginia were estimated by correcting weekly aerial counts for mean daily residence probability between counts. Daily telemetry locations in mark-resight models were used to estimate mean daily residence probability. The study found that approximately 28 percent and 45 percent more red knots used Delaware Bay in 2004 and 2006, respectively, than was evident from peak aerial counts. In Virginia, the differences were 26 percent and 40 percent, respectively, in the same two years (Cohen et al. 2009, p. 939, 942).

While not a good measure of true population size, the aerial shorebird survey methods used in the Delaware Bay can, however, be used to evaluate trends of migrating red knots. The aerial surveys provide comparative annual counts of numbers of red knots observed once per week during a 5-week survey period in May to early June (Clark et al. 1993, p. 695). From 1982 to 1998, aerial survey counts of migrating red knots on the Delaware Bay varied considerably from year to year, showing a somewhat cyclic trend where high peak years were generally followed by 1 to 2 years of declining peak counts, followed by several years of

rebounding peak counts. During this period, highest recorded peaks of 95,360 and 94,460 birds occurred in 1982 and 1989, respectively, and lowest peak counts of 16,859 and 19,445 birds occurred in 1983 and 1996 (Dunne et al. 1983, pp. 68-70; Clark et al. 1993, p. 702; Niles et al. 2007, p. 82).

From 1999-2004, red knot numbers in the Delaware Bay declined, with a peak count of only 13,315 birds in 2004 (Niles et al. 2007, p. 82). Although the 2005 peak count increased to 15,345 (NJDEP 2005, p. 1), the peak counts for 2006 and 2007 were lower, 13,455 and 12,375 red knots, respectively (Clark and Porter 2006, p. 1; 2007, p.1). Thus, although 2005 showed a slight increase over the previous year, there has been an overall long-term declining trend in the red knots at Delaware Bay stopover since the late 1990s. Red knot numbers recorded in 2007 were the lowest recorded in the 22-year history of the Delaware Bay aerial shorebird survey (NJDEP 2007, pp. 12-13). The 2008 red knot peak count in the Delaware Bay was 15,395 birds, an increase of 3,020 birds above the 2007 count and 1,420 birds higher than the average peak count of the preceding 5 years (K. Clark pers. comm. 2008; Dey et al. 2008, p. 1).

In recent years, the highest concentrations of red knots at the Delaware Bay stopover have been within Mispillion Harbor, Delaware. Aerial surveys covering the shoreline of Delaware Bay provided inadequate coverage of a high-use foraging area within the Harbor. Beginning in 2009, a new survey methodology was implemented for the Delaware Bay stopover area to include ground counts that more accurately reflect concentrations of red knots using Mispillion Harbor and to include aerial surveys of red knots using Atlantic coastal marshes near Stone Harbor, New Jersey. The highest aerial count in 2009 (calibrated with ground counts) was 16,229 red knots; however, poor weather conditions in 2009 prevented aerial surveys from May 21 to May 29, so no aerial count occurred in that year during the period when red knots were thought to be at a peak. The highest 2009 ground count of 27,187 red knots occurred on May 26 with the majority of red knots counted in Mispillion Harbor, only a few hundred elsewhere in Delaware, and 900 in New Jersey (Niles et al. 2010, p. 3). It is important to note that this increase in red knots observed in 2009 does not necessarily represent an increase in the red knot stopover population, but rather reflects an improved survey methodology and a wider survey area. In 2010, the peak aerial count of red knots was 14,475. In 2010, flight delays and scheduling issues prevented simultaneous aerial and ground counts so aerial counts could not be calibrated (NJDEP 2010, pp 23-26). Further analysis is needed to correlate peak counts using the new methodology with the past aerial-survey-only counts.

Counts of spring migrant red knots within the Delaware Bay provide an index of the status of the species using the Bay, but do not necessarily represent the total population of spring migrants along the eastern seaboard. In 2005, for example, the peak aerial count for Delaware Bay was 15,345 red knots (NJDEP 2005, p. 1). However, in May 2005, an aerial survey for red knots along Virginia's barrier islands recorded an estimated 9,150 knots (Watts and Truitt 2005, p. 145), and a peak count of approximately 20,000 red knots was reported on the same survey date from ground counts of an Atlantic coastal site in New Jersey, where most Delaware Bay red knots are believed to congregate at a nighttime roost (Sitters 2005, pp. 5-6). Thus, more red knots were accounted for during the spring 2005 migration than are reflected by the Delaware Bay peak aerial count for that year.

Since 2006, the New Jersey Endangered and Nongame Species Program (NJENSP) has coordinated a count of red knots along the United States Atlantic coast from Florida to New Jersey. The count occurs over two consecutive days during the period of May 20 to 24 when it is thought that red knot numbers peak along the coast as a whole. Counts were patchy during 2006 and 2007, with incomplete coverage of the States (Niles et al. 2010, p. 8). Surveys since 2008 have been more comprehensive, but still do not represent complete coverage of all coastal areas with known red knot use. Numbers of red knots counted during the coast-wide survey remained stable during the 3-year period from 2008 to 2010 with red knot counts of 27,532 in 2008, 21,844 in 2009, and 25,328 in 2010 (NJDEP 2010, p. 26). These numbers remain well below the historic estimated Atlantic coast flyway population of 100,000 to 150,000 red knots.

In summary, counts of wintering populations of red knots in Tierra del Fuego and Patagonia in 2005 through 2008, showed an overall continued decline (K. Ross pers. comm. 2006; 2007; Niles et al. 2007, pp. 78-80;

R.I.G. Morrison pers. comm. 2008) consistent with the trend predicted by Baker et al. (2004, pp. 879-881). Red knots showed some increases in 2009, followed by declines in both 2010 and 2011. While these annual fluctuations in wintering counts should continue to be assessed as an indicator of any further population collapse or signs of recovery, it is more useful to look at longer term trends rather than year to year variability. Numbers of red knots remain low as compared to historical numbers and there has been no indication of recovery (R.I.G. Morrison pers. comm., 2007; Niles et al. 2010, p. 2).

## Threats

### **A. The present or threatened destruction, modification, or curtailment of its habitat or range:**

#### **Reduced Forage Base in Habitat at Delaware Bay Migration Stopover**

Commercial harvest of spawning horseshoe crabs in the Delaware Bay, which results in reduced availability of horseshoe crab eggs, is a modification of habitat associated with the decline of the red knot. Reported commercial harvest of horseshoe crabs for the bait and biomedical industry increased dramatically in Delaware Bay in the mid-1990s. In addition to harvest by trawl, crabs were hand-harvested as they ascended onto Delaware Bay beaches to spawn, coinciding with the period when migrating red knots and other shorebirds were foraging on crab eggs. Concern was raised about the negative effect that horseshoe crab harvest might have on shorebirds during migration (USFWS 2003, p.5).

Long-distance migrant shorebirds are highly dependent on the continued existence, in good condition, of habitat at a few key staging areas. These areas serve as stepping stones to northerly breeding areas (International Wader Study Group 2003, p. 10). The Delaware Bay of Delaware and New Jersey serves as the principal spring migration staging area for the red knot (Morrison and Harrington 1992, p. 76; Harrington 1996, p.73; Harrington 2001, p. 7). Conditions / factors influencing shorebird populations on staging areas such as the Delaware Bay control much of the remainder of the annual cycle and survival of the birds. Declining food resources and reduced suitability of staging areas have major implications for the survival and reproduction of these migrants (International Wader Study Group 2003, p. 10).

From 1997 to 2002, Baker et al. (2004, p. 875) found that an increasing proportion of red knots leaving the Delaware Bay failed to reach threshold departure masses of 180 to 200 g, possibly because of later arrival in the Bay and food shortages from commercial harvesting of horseshoe crabs. This reduced nutrient storage, especially in late-arriving birds, had severe fitness consequences for adult survival and recruitment of young in 2000 to 2002: annual survival of adults decreased by 37 percent between May 2000 and May 2001 and the number of second-year birds in wintering flocks declined by 47 percent (Baker et al. 2004, p. 875).

Harvest of horseshoe crabs for the bait industry has been implicated as the primary causal factor in the decline of spawning horseshoe crabs that occurred within the Delaware Bay in the late 1990s. There is a long history of horseshoe crab harvest in Delaware Bay for a variety of uses. In the late 1800s and early 1900s, horseshoe crabs were commercially harvested for use as fertilizer and livestock feed. Millions of crabs were harvested annually from the 1870s to the 1930s at which point commercial landings appear to have dropped significantly. Commercial harvest of horseshoe crabs for fertilizer ceased in the 1960s (Atlantic States Marine Fisheries Commission [ASMFC] 1998a, p. 3). No information is available on how these historic harvests of horseshoe crabs may have affected populations of red knots or other migratory shorebirds.

Since the mid- to late 1900s, horseshoe crabs have been commercially harvested primarily for use as bait and to support a biomedical industry. Horseshoe crabs are the preferred bait in the mid-Atlantic for the American eel (*Anguilla rostrata*) and whelk and conch (Family Melongenidae) pot fisheries; the crabs are also harvested to a lesser extent for use as bait in catfish (*Ictalurus spp.*) and killifish (*Fundulus spp.*) fisheries



(ASMFC 1998a, p. 3; 2004, p. 11). Between 1970 and 1990, reported commercial harvest of horseshoe crabs on the Atlantic coast of the United States ranged from less than 20,000 pounds to above 2 million pounds annually. Reported harvest increased during the late 1990s to nearly 6 million pounds in 1997, and over 6.8 million pounds in 1998 (ASMFC 2004, p. 11). The increase in harvest of horseshoe crabs during the 1990s was largely due to increased use as whelk bait. According to National Marine Fisheries Service (NMFS) records, landings by the whelk pot fishery increased during the 1990s, and were positively correlated with horseshoe crab landings. In contrast, commercial landings by the American eel pot fishery in Atlantic states declined from 1990 to 1998 during the period when horseshoe crab landings increased. Eel and horseshoe crab landings were negatively correlated during that time. The American eel pot fishery prefers egg-laden female horseshoe crabs, while the conch pot fishery uses both male and female horseshoe crabs (ASMFC 2009b, p. 1).

Prior to 1998, horseshoe crab harvests were unregulated in many States (ASMFC 2004, p.11). Beginning in 1998, States were required to report the number of horseshoe crabs landed to the ASMFC. Subsequent regulations by the ASMFC and member states and wide-spread use of bait savings devices have substantially reduced the number of horseshoe crabs harvested for bait. In 1998, over 2.7 million horseshoe crabs were landed on the Atlantic coast of the United States. Reported landings decreased to just over 1 million crabs in 2001 and 2003 (Meyer et al. 2005, p. 11) and showed a further decrease to only 681,000 crabs in 2004. Reported landings in 2005 and 2006 were 759,000 and 841,000, respectively (Horseshoe Crab Technical Committee 2008, p. 5; ASMFC 2008, p. 2; 2009b, p. 40). Landings in 2007, were 827,500 crabs and dropped to a low of 660,000 crabs in 2008. Preliminary 2009 landings are about 734,500 crabs (ASMFC 2009b, p. 40; S. Michels pers. comm. 2010). From 2004 to 2009, annual landings of horseshoe crabs have been reduced by over 70 percent from the reference period landings of the mid to late 1990's (ASMFC 2008, p. 2; 2009b p. 40; S. Michels pers. comm. 2010). For Delaware and New Jersey, the decline in horseshoe crab landings for bait decreased from 726,660 reported in 1999, to 173,777 reported in 2004 and 241,519 in 2005. No horseshoe crabs have been landed for bait in New Jersey since 2007 as a result of a State-imposed harvest moratorium. Landings in Delaware were 147,813 in 2006, a low of 76,663 crabs in 2007, 102,113 in 2008 (Meyer et al. 2005, p. 11; Horseshoe Crab Technical Committee 2008, p. 5; ASMFC 2008, p. 2; 2009b, p. 40), and a preliminary number of 102,659 crabs in 2009. Harvest in Delaware has been limited to males only from 2007 to 2009. As required by ASMFC, Delaware planned to adjust its 2010 horseshoe crab harvest to 95,228 crabs to account for harvest overages occurring in 2008 and 2009 (DE DNREC 2010, p. 1; S. Michels pers. comm. 2010).

In addition to their value in the bait industry, horseshoe crabs are vital to the biomedical industry for detection of bacterial endotoxins in pharmaceuticals. The major biomedical use of horseshoe crabs is the production of *Limulus* Amebocyte Lysate (LAL). The LAL is a clotting agent in horseshoe crab blood that allows detection of endotoxins pathogenic to humans in drugs and intravenous devices. The LAL test was commercialized in the 1970s and is currently the worldwide standard for screening medical equipment for bacterial contamination. In addition, horseshoe crab blood has recently been found useful in cancer research. Blood from horseshoe crabs is obtained by collecting adult crabs, extracting a portion of their blood, then releasing them alive. Prior to 2004, no records were kept on biomedical harvest; estimates of horseshoe crabs collected on the Atlantic coast for the biomedical industry range from 200,000 to 250,000 crabs per year (ASMFC 2004, p. 12). Harvest records beginning in 2004, indicate an increase in biomedical harvest to more than 510,000 crabs in 2008, of which 402,000 crabs were bled. ASMFC assumes a constant 15 percent mortality rate for bled crabs that are not returned to the bait fishery (ASMFC 2009b, p. 3).

In 1998, in response to concerns that horseshoe crab harvest may have a negative effect on food resources for migrating shorebirds, the ASMFC prepared a Horseshoe Crab Stock Assessment and an Interstate Fishery Management Plan for Horseshoe Crab. At the time these planning efforts were implemented, the status of horseshoe crab populations along the Atlantic Seaboard was poorly understood due to limited information collected regarding stock levels. In addition, basic information regarding age and growth rates, recruitment, and population dynamics was lacking (ASMFC 1998b, p. 1). Beginning in 1999, the ASMFC imposed reduced State quotas for horseshoe crabs harvested for the bait industry. In 2000, ASMFC recommended that

NMFS implement a 30 nautical mile radius horseshoe crab harvest closure (including for biomedical use) off the mouth of Delaware. In March 2001, the NMFS established the Carl N. Shuster, Jr. Horseshoe Crab Reserve, an area of nearly 1,500 square miles closed to horseshoe crab harvest in federal waters off the mouth of Delaware Bay.

In 2003, the State of New Jersey implemented restrictions on hand harvest of horseshoe crabs and closed key Delaware Bay spawning / foraging beaches to public access. The State of Delaware implemented similar regulations in 2004. Quotas for New Jersey, Delaware, and Maryland were further reduced by the ASMFC in 2004.

In addition to the regulations already in effect for 2005, and in response to the late arrival of the red knots in Delaware Bay, New Jersey imposed an emergency moratorium temporarily halting the hand harvest of horseshoe crabs until June 23, 2005, to allow the birds continued unencumbered access to foraging areas. The State of Delaware also supplemented its regulations in 2005, by instituting mandatory horseshoe crab check stations. In 2005, although the horseshoe crab hand harvest season in Delaware was scheduled to remain open until June 30, the State reached its 150,000 quota earlier, and closed all harvest effective June 24, 2005. With regulations passed in 2005, Delaware closed the 2006 harvest season from May 1 to June 7, 2006.

The ASMFC's Horseshoe Crab Management Board met in May 2006 and adopted restrictions, with an exemption for harvest for biomedical use, effective from October 1, 2006 to September 30, 2008, including a prohibition on harvest and landing of horseshoe crabs in New Jersey and Delaware from January 1 through June 7, harvest of males only from June 8 through December 31, and harvest limited to no more than 100,000 horseshoe crabs per state per year. Based on horseshoe crab tagging release and recapture information, at least a portion of crabs harvested in Maryland and Virginia waters are of Delaware Bay origin. Therefore, the ASMFC also adopted other restrictions applicable to Maryland and Virginia (ASMFC 2006, p. 4).

New Jersey established regulations in 2006, which superseded ASMFC restrictions; resulting in a moratorium on all horseshoe crab harvest in New Jersey from May 15, 2006 through June 7, 2008. In March 2008, New Jersey passed legislation imposing an open-ended moratorium on horseshoe crab harvest or landing within the State until such time as the red knot has fully recovered.

In February 2007, Delaware imposed a two-year moratorium, effective January 1, 2007, on harvest of horseshoe crabs within Delaware lands or waters. In June 2007, following litigation by two businesses involved in the harvesting and sale of horseshoe crabs, Delaware's moratorium was overturned. Consequently, Delaware developed regulations allowing for a male-only horseshoe crab harvest, consistent with restrictions adopted by ASMFC.

In September 2008, the ASMFC Horseshoe Crab Management Board approved an addendum (Addendum V) extending these harvest restrictions through October 31, 2009 (ASMFC 2008, p. 1, 4). In August 2009, the ASMFC Horseshoe Crab Management Board extended the provisions of Addendum V through October 31, 2010 (ASMFC 2009b, p. 3). In August 2010, the ASMFC Horseshoe Crab Management Board approved Addendum VI, extending the provisions of Addendum V through April 30, 2013.

Beginning April 2009, to provide further protection to the Atlantic coast population of horseshoe crabs and increase the availability of horseshoe crab eggs in Delaware Bay to hemispheric migratory shorebird populations, the Maryland Department of Natural Resources implemented a 2:1 male to female horseshoe crab harvest ratio within Maryland waters. No change in the total harvest quota was made (MD DNR 2009, p.1).

In 2007, the ASMFC Horseshoe Crab Technical Committee and USFWS Shorebird Technical Committee met and endorsed development of a structured decision making and adaptive management approach to horseshoe crab harvest management constrained by red knot conservation. The committees formed an adaptive resource management (ARM) working group and tasked the group with developing an adaptive

management framework. The ARM framework includes objectives, alternative harvest policies, predictive models, monitoring programs, and procedures to update the predictive models (ASMFC 2009a, pp. 2-39). Uncertainty associated with both horseshoe crab and red knot populations is incorporated throughout the ARM framework. The objective statement and utility functions were developed jointly by the Horseshoe Crab and Shorebird Technical Committees. The utility functions specify the value placed on harvest as a function of the population sizes of both species. To achieve multi-species objectives, harvest of female horseshoe crabs is devalued when red knot and female horseshoe crab abundance are low, and male harvest is devalued when horseshoe crab population sex ratio limits population growth rate. Five alternative harvest policies are considered ranging from full moratorium to a maximum harvest of 420,000 males and 210,000 females, including two male only harvest options. The linked population models for horseshoe crabs and red knots in the Delaware Bay predict the consequences of the alternative harvest levels on both horseshoe crabs and red knots. Application of the ARM framework results in an optimization table that recommends harvest policy for all possible combinations of population levels. The policy recommendations take into account ecological and environmental uncertainty. Finally, the ARM framework made recommendations for improving current population monitoring efforts that will reduce uncertainty in the predictive models over time (ASMFC 2009a, pp. 2-39). In November 2009, the ASMFC convened a peer review panel to evaluate the horseshoe crab stock assessment and the ARM framework. The peer review panel endorsed a shift towards a management strategy for horseshoe crab in Delaware Bay that incorporates the ARM framework (ASMFC 2009c, p. 17). Adoption of the ARM framework is one of several horseshoe management options under review in 2011 by the ASMFC.

While management actions by the ASMFC and State fisheries agencies have reduced harvest and will work toward increasing availability of horseshoe crab eggs for migrating shorebirds in the long-term, significant benefits from these management actions are not realized immediately. The horseshoe crab is relatively long-lived and slow to mature, reaching breeding age at about 10 years of age (ASMFC 2004, p. 7); thus there would likely be at least a 10-year lag time between new fishery restrictions and the full effect of changes on horseshoe crab populations (ASMFC 2004, p. 31). It may be difficult to determine changes in horseshoe crab populations even when they occur. An initial horseshoe crab stock assessment concluded in 1998 that there was insufficient information available for a coast-wide assessment of horseshoe crab populations. Data available at the time suggested that the horseshoe crab population in the mid-Atlantic region was stable or declining (ASMFC 1998a, p. 17) and additional attempts to assess coast-wide or regional horseshoe crab populations were highly variable, with low power to detect population changes. Using models and information available during a 2004 stock assessment, it was only possible to detect dramatic changes in horseshoe crab population size (ASMFC 2004, p. 31).

Trawl surveys (conducted during the fall) for all demographic groups of horseshoe crabs show an increasing trend in the Delaware Bay core area from 2003 to 2007 for immature and primiparous (newly mature, but not yet spawned) horseshoe crabs and an increasing trend from 2004 to 2007 for multiparous (mature and have spawned) horseshoe crabs. However, the increasing trends in the core Delaware horseshoe crab area were not mirrored in the peripheral area (Hata 2008, pp. 3-4). Trawl surveys in 2008, showed slight decreases over 2007 for nearly all demographic groups of horseshoe crab, with only primiparous females increasing from the previous year (Hata and Hallerman 2009, pp. 2-3). Stratified mean catches per tow for all horseshoe crabs, and for newly mature and mature demographic groups, were lower in 2009 than in 2008, although not significantly so. Within the core area, mature crabs and newly mature males continued decreasing from 2007, although only newly mature males were significantly less abundant in 2009 than in 2007. Only immature horseshoe crabs increased from the previous year, reversing a decrease from 2007 to 2008. Immature males and females were significantly more abundant in 2009 than in 2003, the lowest in the time-series. In contrast to the core area, 2009 mean catches of immature crabs increased three-fold in the peripheral area following consistent levels from 2002 to 2008, although the increase was not significant. Mean catches of newly mature and mature crabs in the peripheral area remained generally consistent since 2002 (Hata and Hallerman 2010, pp. 3-5). Size-frequency distributions in the Delaware Bay survey area indicate continued recruitment of small horseshoe crabs to the Delaware Bay area (Hata and Hallerman 2009, p. 2-3) with a substantial increase in numbers of the smallest sizes of immature males and females in 2009 over previous years (Hata and

Hallerman 2010, p. 4). The continued increase in immature males and females would be expected in a recovering population and suggests recent harvest restrictions may be having the desired effect, but it may be a few more years until this increase is realized in primi- and multiparous adults (Sweka pers. comm. 2010). Trawl survey information for 2010 is not yet available.

A redesigned Delaware Bay horseshoe crab spawning survey showed that spawning activity was stable or slightly declining from 1999 to 2004 (Meyer et al. 2005, p. 6). A surplus production model study by Davis et al. (2006, p. 222) concluded that the horseshoe crab population in the Delaware Bay region had been depleted and 2004 harvest levels may be too high to allow the population to rebuild within 15 years. Updated spawning information following implementation of additional harvest restrictions shows that female horseshoe crab spawning activity in Delaware Bay has been stable for the overall period of 1999 to 2009 and male horseshoe crab spawning increased during that period (Michels et al. 2008, pp. 7-9; 2010, pp. 8-9). Water temperature may influence the timing of horseshoe crab spawning. In 2008, a strong nor'easter storm hit the Delaware Bay on May 12 causing water temperatures to drop and remain low through much of May. These low water temperatures are thought to have contributed to low horseshoe crab spawning activity in May 2008 (Michels et al. 2009, p. 5). While harvest regulations have substantially reduced the number of horseshoe crabs harvested, numbers of spawning females had not shown a significant increase through 2009. Horseshoe crab spawning numbers for 2010 are not yet available.

Surveys of horseshoe crab eggs on beaches in New Jersey showed a significant decline in the density of eggs in the upper 5 cm of sand for the period of 1996 to 2005 as compared to egg counts from the mid-1980s and early 1990s (Niles et al. 2007, p. 58). This decline would affect red knots more significantly than other shorebird species since red knots feed on surface eggs by pecking rather than probing deeply like some other shorebird species (Tsipoura and Burger 1999, p. 641; Gillings et al. 2007, p. 503). Typically, eggs are laid by horseshoe crabs at the high tide line at depth of 15 to 20 cm (Botton et al. 1992, p. 290). Eggs laid at this depth would make them unavailable to foraging red knots, but the action of multiple female crabs nesting within a particular beach exhumes eggs onto the surface making them available to foraging red knots (H.J. Brockmann pers. comm. 2006). When numbers of spawning horseshoe crabs are reduced, insufficient "churning" of sediments containing previously laid nests occurs, preventing eggs from being exposed at the surface. Various foraging studies have shown that an individual red knot needs to consume between 13,000 and 30,000 horseshoe crab eggs per day during the Delaware Bay stopover to build fat reserves to meet the energetic requirements of migration to and surviving the first few days on Arctic breeding areas (Haramis et al. 2007, pp. 370, 373; Niles et al. 2007, p. 48). Using data derived from feeding trials of 10 temporarily held captive red knots, Haramis et al. (2007, p. 373) calculated that a hypothetical population of 40,000 red knots, requiring an average 80-g increase in body mass per bird to reach migratory condition, would need to consume an estimated 16 billion horseshoe crabs eggs during the Delaware Bay stopover period. While there is a high degree of uncertainty in this calculation, these values underscore the large quantity of horseshoe crab eggs required to refuel shorebird populations during the Delaware Bay spring stopover (Haramis et al. 2007, p. 373). Thus, there must be very high numbers of female horseshoe crabs nesting synchronously in order to provide the superabundance of surface eggs needed to support migrating red knots (H.J. Brockmann pers. comm. 2006; Haramis et al. 2007, p. 373). Gillings et al. (2007, p. 512) found that shorebird intake rates from surface eggs were up to three times higher than those from buried eggs. In most situations, an abundance of surface eggs is critical for individual birds to maximize their intake rate and achieve the mass gains necessary for ongoing migration and subsequent breeding (Gillings et al. 2007, p. 513). This may be especially true for red knots, which have higher energetic demands owing to their large body size and consumption of small prey items (Gillings et al. 2007, p. 503).

Beginning in 2005, Delaware and New Jersey cooperatively adopted a Baywide core sampling method to monitor horseshoe crab eggs available to shorebirds. Horseshoe crab egg densities are ephemeral and can change daily based on conditions of tide, weather, and shorebird density / predation. There is also high seasonal spatial and temporal variability. High egg densities in Mispillion Harbor, Delaware, continue to drive the Baywide trend both spatially and temporally. A composite Baywide index, therefore, does not accurately reflect conditions on Delaware Bay for migratory shorebirds and examination of trend by state is

more informative. In 2009, higher egg densities were observed on 8 of 10 New Jersey beaches sampled in previous years (Kalasz et al. 2010, pp. 1-2, 8-11). Mean New Jersey egg densities in 2009 and 2010 were improved over 2006–2008, but were no higher than the mean density observed when Baywide surveys began in 2005. Egg densities in New Jersey have remained low and have not substantively improved during the period of Baywide sampling (2005–2010) (Kalasz et al. 2010, pp. 1-2, 8-11; Dey and Niles 2011, p. 4).

On Delaware beaches, excluding Mispillion Harbor, the mean horseshoe egg densities declined during the Baywide sampling period of 2005 to 2009. In 2010, mean egg densities were substantially higher than all previous years sampled. Mean Delaware egg density, including Mispillion Harbor, was 136,051 eggs/square meter ( $\text{m}^2$ ) in 2010, as compared to the previous (2009) density of 42,396 eggs/ $\text{m}^2$ . In 2010, Mispillion Harbor was again the Delaware site with the highest egg densities, with the mean density topping 1 million eggs/ $\text{m}^2$ . Other Delaware sites also showed significant increases in egg density in 2010. In particular, average densities at Pickering Beach topped 60,000 eggs/ $\text{m}^2$  and Kitts Hummock surpassed 100,000 eggs/ $\text{m}^2$  (Kalasz et al. 2010, pp. 1-2, 8-11; Kalasz and Weber 2010, p. 4).

In a recent study, Fraser et al. (2010, p. 96) found that shorebirds foraged disproportionately within horseshoe crab nests. There was a greater concentration of shorebird activity sign (e.g. pecks, probes, and digit marks) in horseshoe crab nest plots as compared to control plots elsewhere on the beach, showing that shorebird foraging activity was higher in horseshoe nest depressions than elsewhere on the beach. The greater number of eggs in the top 5 centimeters (cm (2 inches (in))) of crab nests, compared to control plots, indicates that birds foraging in horseshoe crab nests depressions were likely to find richer food supplies than birds foraging on random beach plots (Fraser et al. 2010, p. 97). Thus, while the Delaware Baywide egg survey may have some utility in assessing overall horseshoe crab egg abundance between sites or between years, it would not reflect the densities of eggs present within the swash zone and horseshoe crab nest depressions being preferentially chosen by shorebirds. Even when mean densities of horseshoe crab eggs on a beach are low, birds may be able to find nest depression and forage in very high egg density patches (Fraser et al. 2010, p. 99). Pecking surface eggs is more profitable under most natural conditions, explaining why shorebirds congregate in sheltered bays and river mouths where low wave energy allows eggs to settle on the sand surface. Surface egg densities are renewed as the tide edge recedes, making it possible for birds to sustain high intake rates for longer periods (Gillings et al. 2007, p. 512-513).

When sufficient crab eggs are available, red knots arriving in late May have flexibility to increase the rate of mass gain to over three times the mean rate to “catch-up” with earlier arriving birds (Atkinson et al. 2007, p. 893). Red knots leaving the Delaware Bay weighing greater than ( $>$ )180 g have higher adult survival than birds departing at lower weight (Baker et al. 2004; pp. 1-2). Captures of red knots within Delaware Bay during spring migration show that the proportion of red knots achieving a departure weight of greater than or equal to ( $\geq$ )180 g dropped dramatically from 1998 through 2003 and then remained low through 2007 (NJDEP 2007, pp. 13-14). The gain in muscle and fat to achieve a body mass threshold departure weight of  $>$  180 g is critical not only to fuel migration to the Arctic and to sustain the transformation from a physiological state needed for migration to one needed for successful breeding, but also for continued survival. Red knots estimated to be of low mass toward the end of May are less likely to be subsequently resighted within the flyway, indicating negative fitness consequences of low body weights (Atkinson et al. 2007, pp. 890-891).

Atkinson et al. (2007, p. 892) found that in 2000, 2003, and 2005, weight gain could be attributed to a combination of foraging and weather conditions within Delaware Bay. The estimated proportion of red knots meeting threshold departure weight from 2005 to 2007, was below 30 percent (NJDEP 2007, pp. 13-14). In 2008, horseshoe crab spawning activity was reduced during the shorebird stopover period as a consequence of a strong May 12 nor’easter storm that altered horseshoe crab spawning habitat and lowered water temperatures. As a result, only 14 percent of red knots achieved a mass of  $>$ 180 g by May 26-28, 2008. In 2009, weather was favorable, with no severe weather events occurring during the May shorebird stopover period. The proportion of red knots achieving a mass of  $>$ 180 g by May 26-28 in 2009 was 34 percent. However, this may be an underestimate of the true proportion of red knots attaining threshold weight gains in 2009 as many knots were observed leaving the Delaware Bay during this period, presumably having already

achieved a favorable departure mass (Niles et al. 2010, p. 4). This weight gain indicates that red knots found sufficient horseshoe crab eggs (K. Kalasz pers. comm. 2009; L. Niles pers. comm. 2009) and/or alternate forage resources during the 2009 stopover. In 2010, peak horseshoe crab egg density occurred during the peak shorebird migration, indicating that horseshoe crab spawning and shorebird migration were synchronous that year (Kalasz and Weber 2010, p. 4). As a result, 43 percent of the red knots stopping in Delaware Bay in 2010 reached the 180 g threshold departure weight. This is an improvement over the previous two years, but the proportion of red knots attaining 180 g prior to departure is still well below that recorded in the late 1990s (NJDEP 2010, p. 22).

### **Decreased Habitat Availability from Beach Erosion and Shoreline Stabilization**

Sea level rise and shoreline erosion have reduced availability of intertidal habitat that is used for horseshoe crab spawning and red knot foraging within the principal migration stopover area of the Delaware Bay. In addition, erosion has also led to loss of sites used by red knots for roosting, especially around the Mispillion Harbor portion of the Bay (Niles et al. 2007, pp. 154-155).

The Delaware Bay's sandy beaches are dynamic, migrating landward from storm overwash and retreating landward in the face of continued sea level rise. While future rates are hard to predict, the current level of sea level rise in the Delaware Bay in New Jersey is generally thought to be about 3 millimeters (mm (0.12 in) per year (Phillips 1986a, p. 430). This change has resulted in erosion of the Bay's shorelines and a landward extension of the inland edge of the marshes. During 1940-1978, Phillips (1986a, pp. 428-429) documented a mean erosion rate of 3.2 meters (10.5 feet (ft)) per year for a 52km (32.3 mi) long section of New Jersey's Delaware Bay Cumberland County shoreline and indicated that this was a high rate of erosion compared to other estuaries. The spatial pattern of the erosion was complex, with differential erosion resistance related to local differences in shoreline morphology (Phillips 1986b, pp. 57-58). Phillips' shoreline erosion studies (1986a, pp. 431-435; 1986b, pp. 56-60) suggest that bay-edge erosion is occurring more rapidly than the landward/upward extension of the coastal wetlands and that this pattern is likely to persist.

Galbraith et al. (2002, pp. 177-178) examined several different scenarios of future sea level rise and projected major losses of intertidal habitat in Delaware. Under the 50 percent probability scenario, Delaware Bay is predicted to lose 20 percent or more of the shorebird intertidal feeding habitats by 2050 and 57 percent or more by 2100. Under more extreme sea level rise, Delaware Bay may actually have a net gain of intertidal flats as the coastline migrates further inland, converting dry land to intertidal (Galbraith et al. 2002, pp. 177-178). However, this prediction assumes that coastal protection structures do not constrain the ability of shorelines to migrate landward (Niles et al. 2007, p. 155).

Within the Delaware Bay system, as elsewhere in the Mid-Atlantic region, coastal development and shoreline protection activities are expected to interfere with the longer-term landward migration of shorelines (Najjar et al. 2000, p. 223; Niles et al. 2007, p. 155). Though Delaware Bay is less developed than many similar stretches of Mid-Atlantic coastline, some optimal crab-spawning beach habitat is also the site of existing shoreline residential development. Significant sections of the Delaware Bay shoreline have already been impacted by shoreline protection/ stabilization projects. Coupled with continuing sea level rise and shoreline erosion, the demand for additional shoreline protection structures is expected to increase (Najjar et al. 2000, p. 228; Niles et al. 2007; p. 155). Shoreline stabilization or armoring projects employing bulkheading, riprap or other solid beach-fill can either completely eliminate intertidal sand beach habitat or sufficiently alter sediment quality and beach morphology to negatively affect the suitability of the remaining habitat for horseshoe crab spawning (Botton et al. 1988, p. 331; Niles et al. 2007, p. 155).

Beach replenishment through offshore pumping of sandy sediments (as carried out along several sections of the Delaware shore, but not New Jersey) provides an alternative means of beach stabilization (Niles et al. 2007; p. 155). Beach nourishment may restore or improve spawning habitat, provided measures are implemented to minimize adverse project-related impacts on horseshoe crabs and other resources. The ASMFC Fishery Management Plan for Horseshoe Crab provided recommendations regarding beach

replenishment. Specifically, borrow areas for beach nourishment should be located offshore to avoid adverse impacts on essential juvenile habitat (nearshore, shallow water, subtidal flats). The grain size of renourishment material should be similar in size to the grain size that currently exists on the beach. Construction activities should avoid critical spawning and juvenile development periods. In the mid-Atlantic region, the generally recommended seasonal restriction is from April 15 to August 30 (ASMFC 1998b, p. 28).

Niles et al. (2007, pp. 155-156) also identified shoreline stabilization and/or beach replenishment as a threat to red knot foraging or roosting habitat in Massachusetts and North Carolina. In Florida, shoreline hardening, dredging, and beach nourishment activities are significantly altering much of the coastline, decreasing the amount of available red knot foraging habitat. Similarly, beach raking activities in Florida alter the natural characteristics of the beach zone diminishing red knot habitat suitability.

### **Impacts to Habitat in Canada**

Oil spills are a serious threat to red knot habitat in the Mingan Islands Archipelago (Quebec, Canada). In March 1999, a spill of 40 tons of bunker fuel oil occurred that could have been disastrous if it had happened between mid-July and early-September when red knots were staging in the area. Oil from the 1999 spill did reach the islands used as a red knot foraging / staging area (Y. Aubry pers. comm. 2010), but no information is available about the extent of impacts to prey species from the oil spill. Daily local shipping vessel traffic is expected to increase in 2010 from increased mineral exportation from a local mine, thus raising the potential for an oil spill. Illegal dumping of bilge waste water by some of the 7,000 vessels transiting the St. Lawrence waterway annually is another source of oil and contaminant pollution to red knot foraging habitat and prey resources within the Mingan Island Archipelago (Y. Aubry pers. comm. 2010).

On the Magdalen Islands (Quebec, Canada) clam farming has become a new and growing local business. The clam farming location overlaps with the feeding grounds of transient red knot (adults and juveniles), therefore, some habitat impacts are anticipated. Clam farming extracts all juvenile clams from an area and relocates them in a “nursery area” nearby. The top sand layer (upper 10 cm (3.9 in) of sand) is removed and filtered. Only the clams are kept and the remaining fauna is rejected on the site. This disturbance of benthic (bottom dwelling) fauna could have some impact on the foraging rates and weight gain in red knots and needs to be monitored. This pilot clam farming project could expand into more demand for clam farming in other red knot feeding areas in Canada (Y. Aubry pers. comm. 2010).

### **Impacts to Habitat in South America**

Niles et al. (2007, p. 156) consider offshore petroleum exploration on the continental shelf, as well as iron ore and gold mining, to be among the most important threats to red knots in Brazil. These activities lead to loss of coastal habitat through the dumping of soil, oil pollution, mercury contamination, and uncontrolled spread of urban development along the coast. Clearing of mangroves has had a negative impact on red knot habitat in Brazil by altering the deposition of sediments, leading to a reduction in benthic prey (Niles et al. 2007, p. 156). Specific information on the extent of these impacts is not currently available.

Lagoa do Peixe National Park in Brazil is one of the largest stopover areas for North American migratory birds on the South American continent. The lagoon serves as a major foraging area for red knots. Farmers draining water from farm fields into the lagoon and impacts of erosion and lowering of the water table from adjacent pine (*Pinus* spp.) plantations alter the lagoon’s natural fluctuations and the coastal processes that allow annual connection of the lagoon with the sea. The abundance and availability of the red knot’s food supply are dependent on the lagoon’s water levels (Niles et al. 2007, p. 156).

In Argentina, Niles et al. (2007, pp. 156-157) cited oil pollution as a concern at the Reserva Provincial de Río Chico para Aves Playeras Migratorias and Reserva Urbana Costera del Río Chico, at Bahía Bustamante, and at Península Valdés. At the Bahía San Antonio Natural Protected Area (created in 1993) there is major

potential for pollution from a soda ash factory which began to operate in 2005, and from port activities. Development and associated pollution are concerns at the Reserva Provincial de Río Chico para Aves Playeras Migratorias (created in 2001) and Reserva Urbana Costera del Río Chico (created in 2004). Impacts to these areas include degradation of red knot habitat from filling of tidal flats and marshes for urban use, location of a rubbish dump near shorebird feeding and roosting sites and pollution from urban waste (Niles et al. 2007, p. 157).

At the principal red knot wintering site in Bahía Lomas, Chile, onshore and offshore oil extraction has had a negative impact on red knots and their habitat. Two past oil spill incidents have been recorded in the vicinity: 53 tons from the Metula in 1974 and 100 tons from the Berge Nice in 2004. New Jersey Endangered and Nongame Species Program staff noted oil on some birds caught during banding activities at Bahía Lomas (Niles et al. 2007, p. 157), but the source or amount of released oil or total number of red knots affected is unknown. The magnitude of impact from oil pollution on the red knot and its habitat from past spills is not known; however, since Bahía Lomas supports the majority of wintering red knots in South America (Niles et al. 2007, p. 80, 157; K. Ross pers. comm. 2006), a major oil spill at this site could have a substantial negative impact on the species.

Most of the sites used by red knots at Río Grande on the Atlantic coast of the Argentinean part of Tierra del Fuego are within the Reserva Costa Atlántica de Tierra del Fuego, created in 1992. As at Bahía Lomas, the area is important for on- and off-shore oil production with the potential for oil pollution, especially from oil tankers loading around Río Grande City (Niles et al. 2007, p. 158). Red knots feed close to, and within the mouth of, the Río Grande River. In the past, organic waste from the city of Río Grande (population approximately 50,000), including that from a chicken farm, has been released at high tide over the flats where red knots feed (Atkinson et al. 2005, p. 745). There is no direct evidence of red knots having been affected by oil pollution or organic waste, but it remains a potential risk to the knots and their wintering habitat.

In summary, commercial harvest of spawning horseshoe crabs in Delaware Bay has substantially modified the habitat of the red knot by altering the availability of horseshoe crab eggs, a key food resource and source of energy for the knot as they migrate to breeding areas. Although the ASMFC and the States of Delaware and New Jersey have taken steps to reduce the commercial harvest, it is not clear whether the reduction is sufficient to allow horseshoe crab populations to rebuild. Numbers of spawning female horseshoe crabs have not yet increased and suppressed forage conditions for red knot continue within the Delaware Bay stopover. Research has shown that a high proportion of red knots leaving the Delaware Bay had reduced threshold departure body mass, which appears to have contributed to reduced adult survival and reduced recruitment of young.

In addition to the problems associated with the decrease in horseshoe crab eggs, intertidal habitat used by red knots for foraging in Delaware Bay is being destroyed or modified due to beach erosion. Erosion is occurring as a result of the combined effect of storms and a continued increase in sea level, and continued increases are predicted in association with global climate change. Intertidal foraging habitat also is being destroyed due to various shoreline protection/stabilization projects that either completely eliminate intertidal sand beach habitat or modify it to negatively impact suitability for horseshoe crab spawning. It is not clear that beach replenishment will be an alternative means of beach stabilization or whether it will result in suitable crab-spawning habitat. There also is on-going and threatened habitat destruction and modification in other areas used by migrating red knots along the Atlantic Coast in the United States, and in some wintering habitats in South America, but we are not able to determine the impact to the red knot of the habitat loss in these other areas.

Based on consideration of the best available information, we conclude that the present and threatened destruction, modification, and curtailment of habitat, particularly in the Delaware Bay, continues to threaten the entire *rufa* subspecies of the red knot.



## **B. Overutilization for commercial, recreational, scientific, or educational purposes:**

Red knots were heavily hunted for both market and sport during the second half of the nineteenth and first quarter of the twentieth centuries. For example, market hunters in Massachusetts may have taken up to 4,000 red knots in a single night (Harrington 2001, p. 22). By the late 1890s in New Jersey, red knots (also locally known as robin snipe or gray snipe) were reported to have been formerly very plentiful in migration, but “killed off to a great extent, proving an easy prey for pothunters” (Shriner 1897, p. 94). An account by Wilson (1829, p. 140) reported that red knots (also called red-breasted sandpiper or gray-back) were a particular favorite among gunners, “being generally a plump, tender, and excellent bird for the table,” and consequently bringing a good price on the market. However, hunting red knots is no longer allowed in the United States.

Band recoveries indicate that knots are killed commonly for food in some regions of South America, especially the Guianas. Red knots are also shot for sport in Barbados. Information from band recoveries indicates that the take may be substantial (Harrington 2001, p. 22), but the overall take and its impact on the subspecies is unknown.

Hunting migratory shorebirds for food was once common among local communities in Maranhão, Brazil. Shorebirds provided an alternative source of protein and birds with high subcutaneous fat content, such as those birds found at staging areas building up reserves for long migratory flights, were particularly valued. According to locals, the most consumed species were red knot, black-bellied plover (*Pluvialis squatarola*) and whimbrel (*Numenius phaeopus*), though no data are available as to the number of birds taken. Local people say that although some shorebirds are still hunted, this has greatly decreased over the past decade (Niles et al. 2007, p. 159).

Based on the best available information, while harvest did occur historically throughout the range of the subspecies, only localized hunting still occurs. However, this level of hunting activity impacts some individuals, but overutilization for commercial, recreational, scientific, or educational purposes is not a threat to the entire *rufa* subspecies of the red knot.

## **C. Disease or predation:**

Niles et al. (2007, p. 169) described an introduced breeding population of peregrine falcons (*Falco peregrinus*) as a threat to red knots in Virginia, where peregrines caused frequent interruptions to red knot foraging and roosting. Similarly, several pairs of peregrine falcons on the New Jersey side of the Delaware Bay use artificial nesting structures in proximity to red knot migratory habitats. Peregrine falcons were seen frequently along Gulf beaches in Texas, where dunes would provide good cover to approaching peregrines preying on red knots foraging along the narrow beachfront (Niles et al. 2009, p. 2). While peregrine falcons may pose a risk to some individual red knots, we do not have any information that suggests they pose a risk to the overall population of red knots. Other likely predators of migrating red knots in New Jersey include red fox (*Vulpes vulpes*) and feral cats (*Felis catus*) (Niles et al. 2007, p. 161). No information regarding the magnitude of such predatory impacts is available.

In the Arctic, 3- to 4-year lemming cycles give rise to similar cycles in the predation of shorebird nests. When lemmings are abundant, arctic foxes (*Alopex lagopus*) and jaegers (*Stercorarius spp.*) concentrate on the lemmings and shorebirds breed successfully. When lemmings are in short supply, predators, including arctic foxes, jaegers, snowy owls (*Bubo scandiaca*) gulls (*Larus spp.*), and falcons (*Falco spp.*), switch to shorebird eggs and chicks (Summers and Underhill 1987, p. 169; USFWS 2003, p. 23; COSEWIC 2007, p. 19). These cycles have always affected the productivity of arctic-breeding shorebirds and lead to fairly minor year-to-year changes in otherwise stable populations. Unsuccessful breeding seasons have contributed to at least some of the observed recent reductions in the red knot population (Niles et al. 2007, p. 161) and can be expected to lead to cyclic losses in future years. The cyclical nature of this predation on shorebirds is a

situation that probably has occurred over many centuries and under historic conditions probably had no lasting impact on red knot populations. While there apparently was widespread lack of breeding success in 2004, that was attributed in part to predation, there is no indication that this was anything other than one of the events that happens from time to time and we have no basis for concluding that predation during the breeding season is having a long-term impact on persistence of red knots.

We have limited information on disease (including the impact of parasites) in relation to the red knot. An epizootic (epidemic simultaneously affecting many animals) disease resulting in large-scale mortality of knots reported from the west coast of Florida in December 1973 and November 1974 was caused by a protozoan (single-celled organism) parasite, most likely an undescribed sporozoan (single-celled parasitic organism reproducing by spores) species (Harrington 2001, p. 21). Further reports on knot mortality in Florida in 1981 were due to the blood parasite *Plasmodium hermani* (Harrington 2001, p. 21).

In 1981 there was a report of an adventitious molt (unexpected shedding of feathers) in knots caused by a mallophagan (feather feeding) parasite (also known as bird lice) (Mallophaga: Menoponidae) in feather shafts (Harrington 2001, p. 21).

On April 7, 1997, 26 red knots, 10 white-rumped sandpipers (*Calidris fuscicollis*) and 3 sanderlings (*C. alba*) were found dead or dying along 10 km (6.2 mi) of beach at Lagoa do Peixe in southern Brazil. The following day, another 13 dead or sick knots were found along 35 km (21.7 mi) of beach nearby. Some, but not all of these birds, were infected with hookworms (*Acanthocephala* spp.). Although hookworms can cause death, it would seem more likely that the mortality had another unknown cause. Smaller mortalities of spring migrants with similar symptoms have also been reported from Uruguay in recent years (Niles et al. 2007, p. 161).

Since 2002, migratory birds in Brazil have been tested for viruses including West Nile, Newcastle, and avian influenza by the National Health Foundation in collaboration with Instituto Brasileiro do Meio Ambiente dos Recursos Naturais Renováveis and Centro Nacional de Pesquisa para Conservação das Aves Silvestres. To date, avian influenza type H2 has been found in one red knot, Mayaro virus in seven knots, and Equine Encephalite virus in another (Niles et al. 2007, p. 162).

Since December 2003, blood and feather samples have been collected in Brazil from red knots and several other shorebird species for genetic variability studies and stable isotope analysis. In the course of these studies in February 2005, all 38 knots caught and sampled in Maranhão were found to be heavily infected with ectoparasites. The birds were also extremely light, less than the usual fat-free mass of knots (Baker et al. 2005, p. 15).

No systematic effort has yet been made to assess the parasite load of birds passing through Delaware Bay, but fieldworkers have noticed ectoparasites on a substantial number of knots caught there (Niles et al. 2007, p. 162).

Based on the best available information, while disease and predation occur in individual red knots, these factors do not threaten the entire *rufa* subspecies of red knot.

#### **D. The inadequacy of existing regulatory mechanisms:**

The Migratory Bird Treaty Act (40 Stat. 755; 16 U.S.C. 703-712) (MBTA) is the only current Federal protection provided for the red knot. The MBTA prohibits “take” of any migratory bird, which is defined as: “to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect.” However, other than for nesting sites, which are not located in the United States, the MBTA provides no authority for protection of habitat or food resources. Human disturbance is cited as one of the major threats to red knots throughout its migratory range within the United States. The MBTA does not afford red knots protection from human disturbance on migratory and wintering areas.

Starting in 2003, major sections of the New Jersey shoreline of the Delaware Bay have been closed to human use during the peak of the stopover at the initiative of the New Jersey Division of Fish and Wildlife in order to reduce disturbance to shorebirds by people and dogs. No similar closures have been instituted in Delaware.

In response to concern for impacts to the red knot and other migratory shorebirds, the ASMFC adopted a Fishery Management Plan for the Horseshoe Crab in 1998. Beginning in 1999, the ASMFC imposed reduced State quotas for horseshoe crabs harvested for the bait industry; quotas in the states of New Jersey, Delaware, and Maryland were further reduced in 2004. In 2003, the State of New Jersey implemented restrictions on hand harvest of horseshoe crabs and closed key Delaware Bay spawning / foraging beaches to public access. The State of Delaware implemented similar regulations in 2004.

In 2005, the States of New Jersey and Delaware took additional regulatory action to ensure that the horseshoe crab harvest did not adversely impact the red knot or other migratory shorebirds. In addition to the regulations already in effect for 2005, and in response to the late arrival of the red knots in Delaware Bay, New Jersey imposed an emergency moratorium temporarily halting the hand harvest of horseshoe crabs until June 23, 2005, to allow the birds continued unencumbered access to foraging areas.

The State of Delaware also supplemented its regulations in 2005 by instituting mandatory horseshoe crab check stations. Although the horseshoe crab harvest season in Delaware was scheduled to remain open until June 30, the State reached its 150,000 quota earlier, closing all harvest effective June 24, 2005. Delaware closed the harvest season from May 1 to June 7, 2006.

The ASMFC's Horseshoe Crab Management Board met in May 2006 and adopted the following restrictions, with an exemption for harvest for biomedical use, effective from October 1, 2006 to September 30, 2008: (1) for New Jersey and Delaware there is a prohibition on harvest and landing of horseshoe crabs from January 1 through June 7, harvest of males only is allowed from June 8 through December 31, and harvest is limited to no more than 100,000 horseshoe crabs per state per year; (2) in Virginia, the harvest season is closed from January 1 through June 7, 40 percent of harvest must be from outside state waters, and there is a minimum male to female ratio of 2:1; and (3) in Maryland the season is closed from January 1 through June 7 (ASMFC 2006, p. 4).

New Jersey established regulations in 2006 which superseded ASMFC restrictions; resulting in a moratorium on all horseshoe crab harvest in New Jersey from May 15, 2006 through June 7, 2008. In March 2008, New Jersey passed legislation imposing an open-ended moratorium on horseshoe crab harvest or landing within the State until such time as the red knot has fully recovered.

In February 2007, Delaware imposed a two-year moratorium, effective January 1, 2007, on harvest of horseshoe crabs within Delaware lands or waters. In June 2007, following litigation by two businesses involved in the harvesting and sale of horseshoe crabs, Delaware's moratorium was overturned. Consequently Delaware developed regulations allowing for a male-only horseshoe crab harvest, consistent with restrictions adopted by ASMFC.

In September 2008, the ASMFC Horseshoe Crab Management Board approved an addendum (Addendum V) extending these harvest restrictions through October 31, 2009 (ASMFC 2008, p. 1, 4). In August 2009, the ASMFC Horseshoe Crab Management Board extended the provisions of Addendum V through October 31, 2010 (ASMFC 2009b, p. 1).

Beginning April 2009, the Maryland Department of Natural Resources implemented a 2:1 male to female horseshoe crab harvest ratio within Maryland waters. No change in the total harvest quota was made (MD DNR 2009).

We are encouraged by the States' efforts to restrict horseshoe crab harvest. We believe that continued restrictions at appropriate times and appropriate levels will contribute to the conservation of the red knot.

However, we do not know precisely whether measures described above will be sufficient in the long term to result in restoration of horseshoe crab populations to levels that will result in the abundance of eggs needed for migrating red knots as they increase their body mass prior the breeding season.

In summary, recent changes in regulations pertaining to limits on commercial harvest of horseshoe crab should help stabilize or restore the crab population and the availability of eggs as a food source for the red knot, but due to biological lag time of horse shoe crab recruitment response, the results are currently uncertain. Existing regulatory mechanisms also have not been adequate to address the destruction and modification of intertidal foraging habitat due to erosion and shoreline stabilization involving the Delaware Bay area.

## **E. Other natural or manmade factors affecting its continued existence:**

### **Curtailment of Habitat Use by Human Disturbance**

Human disturbance can have an adverse effect on foraging by shorebirds at available suitable habitats. The severity of the impact depends on the degree of disturbance and the availability of other suitable feeding areas. Disturbance compels birds to pay the energetic cost of flying to a new area; it may reduce the amount of time that the birds are able to feed, and can prevent them from feeding in the most preferred sites. Disturbance, however, may have little impact on birds if suitable alternate foraging areas are nearby in which the birds can feed (Niles et al. 2007, pp. 167-168).

The annual spectacle of shorebirds and spawning horseshoe crabs draws hundreds of bird watchers to Delaware Bay beaches during the spring migratory stopover. Ecotourism in the Delaware Bay has increased since the 1980s and is expected to continue to increase in future years. Negative impacts from ecotourism on shorebirds included disturbance of resting and foraging birds, shifting of use from optimal foraging sites to less disturbed but less suitable sites, and decreasing flock sizes on heavily disturbed beaches (Burger et al. 1995, p. 61). The beaches are also vulnerable to the usual beach activities, such as walking, jogging, fishing and dog walking (Niles et al. 2007, p. 168). Disturbance along the New Jersey shore of Delaware Bay was first investigated in 1982, with further studies in the 1980s, 1990 and 2002 (Burger et al. 2004, p. 285). The results show that the average period that a beach was disturbed during any hour of the day dropped from 32.9 minutes in 1982 to 3.6 minutes in 2002. This decrease was the direct result of increased management efforts by the New Jersey Division of Fish and Wildlife. However, throughout most of the red knot's range, no similar protection from human disturbance is provided to migrating or wintering red knots.

One measure of sensitivity to disturbance is whether the birds return to an area after being disrupted. When shorebirds foraging on beaches are disturbed by people and dogs, the birds usually respond by flying away. In 1982, 30 percent of shorebirds disturbed at Reeds Beach South and 98 percent at Reeds Beach North in New Jersey flew away when disrupted by people and did not return within 10 minutes. In 2002, 98 percent of shorebirds disturbed at Reeds Beach South and 93 percent at Reeds Beach North did not return, with an increasing proportion of disturbance coming from dogs (Burger et al. 2004, p. 286). Burger et al. (2004, p. 287) found that shorebirds flew away and did not return to forage in response to 58 percent or more human disruptions.

In New Jersey, when most beaches were protected from disturbance in 2002, the shorebirds were able to move to nearby beaches that were undisturbed. Therefore, management that restricts human activities on Delaware Bay beaches is shown to be effective in creating disturbance-free beaches necessary for feeding and resting shorebirds. Starting in 2003, major sections of the New Jersey shoreline of the Delaware Bay have been closed to human use during the peak of the stopover at the initiative of the NJDFW in order to reduce disturbance to shorebirds by people and dogs. Before this, disturbance of the beaches was a particular problem, especially during Memorial Day weekend (Niles et al. 2007, p. 168). In 2001, for example, all 18,000 red knots that had previously been feeding on the bayshore spent Memorial Day weekend on the

Atlantic coast in the vicinity of Stone Harbor (Sitters 2001, p. 4) where the birds have been observed feeding on mussel spat, an alternate food source that does not provide the same caloric benefit as fat-rich horseshoe crab eggs.

Similar bay-wide closures of human activities on horseshoe crab spawning/shorebird feeding beaches have not been implemented in Delaware where human disturbance of foraging red knots continues in some locations (K. Bennett pers. comm. 2005). An additional source of human-induced disturbance in Delaware is that caused by off-road vehicle (ORV) use. Although not quantified, shorebird foraging areas within the Delaware shore of the Bay are occasionally used by ORVs. The frequency and duration of this type of disturbance varies, but can have a major impact if ORVs remain at a specific location for an extended period of time. An ORV driving along a beach without stopping may have a relatively insignificant effect. However, when they are used with great frequency or for long periods (such as when ORVs are used for recreation as opposed to transportation), they probably cause shorebirds to leave and not return (Niles et al. 2007, p. 168). With the decrease in numbers of horseshoe crabs and increased loss of available horseshoe crab spawning habitat due to erosion, fewer highly suitable foraging sites are available to red knots. Human disturbance causes disruption of resting and foraging birds and shifting of use from optimal foraging sites to less suitable sites; this could negatively impact the ability of the birds to attain the weight gain needed for migration to the Arctic and successful breeding there.

Disturbance by people is not limited to direct use of Delaware Bay beaches. Low energy beaches, particularly those along the mouths of tidal creeks and rivers, have been identified as optimum horseshoe crab spawning habitat. Where these areas have high levels of boat traffic, such as at Mispillion Harbor in Delaware, disturbance due to the presence, noise, speed, or wake of boats is likely to be considerable. Preliminary results indicate that boat traffic in Mispillion Harbor represents a significant source of disturbance to feeding shorebirds, particularly when boats travel at high speed (Niles et al. 2007, pp. 168-169). Mispillion Harbor consistently supports high concentrations of red knots, sometimes more than 20 percent of the entire Delaware Bay population (Niles et al. 2007, p. 55).

As in the principal migration Delaware Bay stopover area, human disturbance within otherwise suitable red knot migration and winter foraging or roosting areas was reported by biologists as a major negative impact to red knots in Massachusetts, Virginia, North Carolina, South Carolina, Georgia, and Florida. Disturbance in Florida was characterized as chronic with most beaches experiencing very high and increasing rates of disturbance (Niles et al. 2007, p. 169).

In 2008/2009, mean mass of red knots was tracked through the wintering period at Indian Shores and Anna Maria Island in Florida. At both sites the average weight was below the ideal red knot fat-free weight of 131 g, but the difference was much greater at Indian Shores. Average weights of birds at Indian Shores increased from 131 g in October –November 2008 to 134 g in January 2009 and then decreased to 112 g in February 2009. Birds at Anna Maria Island decreased in average weight from 132 g in October – November 2008 to 124 g in January 2009 and remained at this average weight in February 2009. The red knot flock wintering at Indian Shores is subjected to greater human disturbance by beach users than those wintering at Anna Maria Island (Niles 2009, pp. 5-6).

In Quebec, Canada, specifically on the Magdalen Islands, feeding and resting red knot are frequently disturbed by human activities (clam harvesting and associated commercial clam farming activities, kite surfing on beaches and in nearby waters, and seal rookery observation) (Y. Aubry pers. comm. 2010).

On the wintering grounds in Tierra del Fuego, roosting flocks at Río Grande are frequently disturbed by dogs and people engaging in walking, running, and fishing, and operating all-terrain vehicles and motorcycles. In Argentina, disturbance of knots on migration has been reported from Río Gallegos, Peninsula Valdes, San Antonio Oeste, and Bahía Samorombon (Niles et al. 2007, p. 170; COSEWIC 2007, p. 36).

In summary, studies have shown that human disturbance causes a substantial disruption to foraging and

resting red knots. When coupled with diminished prey resources and reduced habitat availability, such human disturbance displaces red knots from optimal foraging sites to areas that may be less suitable. Therefore, the best available information suggests that human disturbance occurring during critical migration periods can result in a negative impact and, while not the primary cause, may be a contributing factor to reduced fitness of red knots. The amount of disturbance may have decreased in some key areas due to closures, but this is unclear.

### **Die-offs from Undetermined Causes / Red Tide Events**

In April 2007, 312 red knots were found dead on the coast of southeastern Uruguay at Playa La Coronilla. Another 1,000 dead shorebirds were found on the same day at nearby site, also in southeastern Uruguay, but could not be confirmed to be red knots. The cause of the shorebird die-off remains undetermined, but is thought to be from a red tide (harmful algal bloom) event (J. Aldabe pers. comm. 2007; BirdLife International 2007). Red knots passing through Uruguay in April would be expected to be those wintering in Tierra del Fuego. A die-off of up to 1,300 red knots would account in large part for the 15 percent decline in red knots wintering within Tierra del Fuego observed in 2008. A die-off of a substantial number of red knots during migration from undetermined causes, as occurred in 2007, is sufficient to pose a threat to the continued existence of the red knot.

A red tide event occurred in 2009 along the Gulf Coast of Texas during the period that migrant/wintering red knots were using the area. Aerosols produced by the red tide were present and affecting human breathing on Padre Island by October 6. Hundreds of thousands of dead fish littered beaches from Mustang Island south into northern Tamaulipas, Mexico over the next two weeks. Most shorebirds became conspicuously absent from Gulf beaches during that time (Niles et al. 2009, pp. 4-5). A red knot that had been captured and banded on October 6, 2009 (Flag # 7MM) was found four days later in poor condition on Mustang Island. The bird was captured by hand and taken to an animal rehabilitation facility at Port Aransas. This bird had been resighted on October 7, the day after its original capture, when it was walking normally and feeding. At the time of first capture the bird weighed 113 g; its weight on arrival at the rehabilitation facility was 78 g (Niles et al. 2009, p. 5). While there is no direct evidence, the red tide event is suspected as the reason for the generally low weights and for the sharp decline in weights of red knot captured on Mustang Island, Texas in October 2009. The average mass of the 63 captured birds (119.4 g) was much lower than average figures for knots caught in Massachusetts and New Jersey in fall 2009 and past years. Nine birds were caught at 110 g or less. Not only was the average mass of all the knots caught on Mustang Island low compared with other sites, but average weights of individual catches declined significantly over the short period of field work (Niles et al. 2009, pp. 3-5) coinciding with the red tide event.

Water samples collected within the area affected by the red tide were confirmed to contain low concentrations of *Karenia brevis* (Niles et al. 2009, Appendix 2), a dinoflagellate that has been implicated in producing harmful algal blooms or "red tides" that occur annually in the Gulf of Mexico. Dinoflagellates are microscopic, unicellular, organisms with long threadlike projections, often photosynthetic protists (single celled organisms capable of converting light energy to chemical energy stored as carbohydrates), commonly regarded as "algae" (Division Dinoflagellata). *Karenia brevis* red tides cause extensive marine animal mortalities and human illness through the production of highly potent neurotoxins (substances toxic to nerves) known as brevetoxins. *Karenia brevis* has come to be known as the Florida red tide organism, and has been implicated in blooms in Louisiana, Texas, Mississippi, Mexico, and the Carolinas (Marine Genomics Project 2010).

### **Gull Competition**

Botton (1984, p. 152) noted that in addition to shorebirds, large populations of laughing gulls were predominant on horseshoe crab spawning beaches in Delaware Bay. During 1992-2002, the number of gulls recorded in single-day counts on Delaware Bay beaches in New Jersey ranged from 10,000 to 23,000 (Niles et al. 2007, p. 170). Gull breeding colonies in Delaware are not located as close to the bayshore beaches as in

New Jersey. However, immature, non-breeding, large gulls such as greater black-backed gull (*Larus marinus*) and herring gull (*L. argentatus*) and some laughing gulls (*L. atricilla*), most likely from New Jersey breeding colonies, do congregate on the Delaware shore during the spring, especially at Mispillion Harbor (Niles et al. 2007, p. 170).

Gulls foraging on the beaches of Delaware Bay may directly or indirectly compete with shorebirds for horseshoe crab eggs. Burger et al. (1979, p. 462) found that intraspecific aggressive interactions of shorebirds were more common than interspecific interactions. Negative interactions between knots and laughing gulls that resulted in disruption of knot behavior were no more prevalent than interactions with ruddy turnstones (*Arenaria interpres morinella*), short-billed dowitchers (*Limnodromus griseus griseus*), or black-bellied plovers. However, larger-bodied species tended to successfully defend areas against smaller species. Total aggressive interactions increased as density of birds increased in favored habitats, which indicated some competition for food resources. Sullivan (1986, pp. 376-377) found that aggression in ruddy turnstones increased as experimentally-manipulated food resources (horseshoe crab eggs) changed from an even distribution to a more patchy distribution. Decisions to defend food patches were likely driven by the cost of locating new patches. The implications of this information for the knot are unclear at this time.

Following up on earlier results, Burger (2005, p. 9) studied foraging behavior in shorebirds and gulls at Delaware Bay, New Jersey, during spring migration to determine if interference competition existed between shorebirds and gulls. In general, shorebirds have conspecifics as their nearest neighbors and, thus, fed in conspecific groups. Similarly, laughing gulls usually fed among conspecifics. Interference competition occurs in foraging flocks if there is a change in feeding rate of a focal bird when it feeds in the presence of different numbers of competitors, or with different species. For knots, the time devoted to foraging when gulls were present was significantly less than when a nearest neighbor was any shorebird. Red knots spent more time being vigilant when their nearest neighbors were gulls rather than other shorebirds. Similarly, knots engaged in more aggression when gulls were nearest neighbors (although they usually lost) (Burger, 2005, p. 10; USFWS 2003, p. 42).

Reduction of available horseshoe crab eggs or consolidation of spawning crabs onto fewer beaches could increase interference competition among egg foragers. Competition between shorebirds and laughing gulls for horseshoe crab eggs has increased in recent years as the decline in the horseshoe crab population has concentrated spawning to a few favored areas (e.g., Mispillion Harbor, Delaware; Reeds Beach, New Jersey). These “hot spots” of horseshoe crab eggs concentrate foraging shorebirds and gulls increasing competition for limited resources. Hot spots can shift in some years when severe wind and rough surf favor spawning in sheltered areas (e.g., creek mouths) (Kalasz et al. 2010, pp 11-12). Botton et al. (1994, p. 609) noted that flocks of shorebirds appeared to be deterred from landing on beaches when large flocks of gulls were present. Red knot foraging efficiency is also adversely affected by the mere presence of gulls: Hernandez (2005, p. 80) found that the foraging efficiency of knots feeding on horseshoe crab eggs decreased by as much as 40 percent when feeding close to a gull.

Gulls are more tolerant of human disturbance than shorebirds. When disturbed by humans, gull numbers returned to pre-disturbance levels within 5 minutes. Even after 10 minutes, shorebird numbers failed to reach pre-disturbance levels. Thus, the size and aggression of gulls, coupled with their greater tolerance of human disturbance, give gulls an advantage over shorebirds in prime feeding areas.

In the present scenario of limited availability of good feeding beaches, competition for food with gulls appears to be an increasing negative impact on red knots in the Delaware Bay (Niles et al. 2007, pp. 170-171). However, we do not know whether the impacts are occurring at levels sufficient to pose a threat to the persistence of the red knot.

## **Wind Energy Development**

Wind energy is increasingly being explored as a renewable energy alternative to use of fossil fuels. Individual

States along the United States Atlantic coast are exploring the feasibility of allowing wind turbine facilities both on land along the Atlantic coast and offshore within State coastal waters. The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly called the Minerals Management Service (MMS), is evaluating areas along the Outer Continental Shelf (OCS) for leases, easements, and rights-of-way for renewable energy project activity (MMS 2007, pp. 2-5). The nation's first lease for commercial wind energy development on the OCS was issued on October 6, 2010, for the Cape Wind Energy Project. The Cape Wind Energy Project 33-year lease calls for 130 turbines, each with a maximum blade height of 440 feet, to be arranged in a grid pattern in 25 square miles of Nantucket Sound in Federal waters offshore Cape Cod, Martha's Vineyard, and Nantucket Island, Massachusetts (BOEMRE 2010, pp. 1, 3). In addition, leases have been authorized for renewable energy resource site assessment and technology testing activities on ten offshore projects related to construction of commercial scale offshore wind farms on the OCS (six off New Jersey, one off Delaware, and three off Georgia) (BOEMRE 2011, p.1).

Burger et al. (2011, p. 341-2) used a weight-of-evidence approach to examine the risks and hazards from offshore wind development on the OCS to three species of coastal waterbirds, including red knot. Three general levels of exposure were identified: macro-scale (occurrence of species within the geographical areas of interest); meso-scale (occurrence within the rotor swept zone or hazard zone, governed by flight altitude); and micro-scale (whether the species is likely to fly within the rotor swept area). Within the OCS, during spring and fall migration red knots have high potential exposure to collision risk for long-distance migrants and low exposure for short distance migrants at the macro-scale, and moderate exposure at the meso-scale since they may descend to (or ascend from) migratory stopovers at critical / vulnerable heights. Further studies of flight heights and behavioral avoidance are necessary to assess hazard levels at the meso- and micro-scales (Burger et al. 2011, p. 342-346). As with other migrants, little information is available on red knot avoidance rates for on, near, or offshore wind power structures. Determining avoidance rates for red knot is critical to estimating meaningful potential mortality from coastal and offshore wind power turbines (Chamberlain et al. 2006, p. 201).

The effect of weather on migrating bird flight altitudes has been well documented through the use of radar and thermal imagery. Numerous studies indicate that the risk of bird collisions with wind turbines increases as weather conditions worsen and visibility decreases (Exo et al. 2003 p. 51; Drewitt et al. 2006, p. 31; Hüppop et al. 2006, p. 102,105-107). If birds are migrating at high altitudes and suddenly encounter fog, precipitation, or strong head winds, they may be forced to fly at lower altitudes, exposing them to increased wind turbine collisions if they fly in the rotor swept zone (Drewitt et al. 2006, p. 31). Avoidance behavior is likely to vary according to conditions. It is reasonable to expect that avoidance rates would be much reduced at times of poor visibility, in poor weather, at night (Chamberlain et al. 2006, p. 199), and under varying structure illumination conditions (Drewitt et al. 2006, p. 31; Hüppop et al. 2006, p. 105). The greatest collision risk occurs at night, particularly in unfavorable weather conditions. Behavioral observations have shown that most birds fly closer to turbine rotor blades at night than during day and that more birds collide with rotor blades at night than by day (Exo et al. 2003, p. 51). Hazards to red knots from wind energy development likely increase for facilities situated closer to shore, particularly near bays and estuaries that serve as major stopover or wintering areas (Burger et al. 2011, p 348).

Collisions with wind energy turbines, particularly during inclement weather and low visibility, is likely to cause periodic, isolated red knot mortality events. However, as most existing coastal wind farms along the United States Atlantic coast are smaller in scale with only a few turbines per site and most large scale coastal projects have not yet become operational, we do not anticipate that impacts are currently occurring at levels sufficient to pose a threat to the persistence of the red knot.

## **Weather and Climate Change**

Water temperature influences the timing of horseshoe crab spawning in Delaware Bay. In cold years, horseshoe crabs spawned later than in warm years (Smith and Michels 2006, p. 489). Weather conditions in May can thus influence the timing of horseshoe crab spawning and availability of horseshoe eggs as forage



for red knots during the stopover period. Since timing of the spring shorebird migration stopover is critically dependent on the availability of horseshoe crab eggs, coastal storms and other weather patterns that result in diminished horseshoe egg availability can have severe fitness consequences for red knots. Atkinson et al. (2007, p. 892) found that in 2000, 2003, and 2005, low weight gain at the spring migration stopover could be attributed to a combination of poor foraging and inclement weather conditions within Delaware Bay. While variation in weather is a natural occurrence and is normally not considered as a threat to the persistence of a species, adverse weather events in Delaware Bay can pose a threat to the red knot by exacerbating reduced availability of horseshoe eggs, resulting in inadequate weight gain of birds during their migration stopover.

While it had been predicted that red knots would have lower survival rates in years of high snow cover, mark recapture/resight modeling of red knots using Delaware Bay showed a positive correlation between survival and Arctic snow depth. Survival of both heavy and light weight red knots was highest in years with greatest snow depth and lowest in years with little snow (ASMFC 2009a, p. 21). Thus, climate change that decreases snowfall within Arctic breeding areas would negatively impact red knot survival.

Adverse weather in the Arctic can cause years with little to no productivity. Conditions for breeding shorebirds are highly variable among sites and regions. Whether or not to breed upon arrival on the breeding grounds, the timing of egg-laying, and the chick-growth period, are factors most affected by annual variation in weather. In much of the Arctic, clutch initiation dates are highly correlated with snowmelt dates and in regions and years where extensive snowmelt occurs before or soon after the arrival of shorebirds, the decision to breed and clutch initiation dates appear to be a function of food availability for laying females. Once incubation is initiated, adult shorebirds appear fairly resilient to variations in temperature with nest abandonment primarily occurring in case of severe weather with new snow covering the ground. Feeding conditions for chicks is highly influenced by weather, affecting juvenile production (Meltotte et al. 2007, p.7).

At a site on Southampton Island in Canada (where breeding red knots have been periodically studied since 1999 by the NJENSP), late snowmelt and adverse weather conditions, combined with predation, contributed to poor productivity in 2004 and may have also significantly increased mortality of adult red knots (L. Niles pers. comm. 2004). Canadian researchers reported that most arctic-breeding birds failed to breed successfully in 2004 (B. Andres pers. comm. 2004). In 2006, within red knot breeding areas in the eastern Arctic and Hudson Bay, Arctic weather conditions were normal to above normal (Canadian Ice Service 2006, pp. 4-17). Variations in weather are a natural occurrence and normally are not considered as a threat to the persistence of a species unless the number of individuals is reduced to a very low level and they are concentrated in an area that is subject to weather conditions that result in mortality and/or poor productivity.

The fate of Arctic shorebirds under projected future climate scenarios is uncertain, but High Arctic species and populations appear particularly at risk. Warming trends may benefit Arctic shorebirds in the short term by increasing both survival and productivity, whereas in the long term habitat changes, both on the breeding grounds and non-breeding areas, may put Arctic nesting shorebirds under considerable pressure, bringing some to near extinction. Relatively low genetic diversity, which is thought to be a consequence of survival through past climatically-driven population bottlenecks, may put shorebirds at more risk to anthropogenic-induced climate variation than other avian taxa (Meltotte et al. 2007, p.7). It is unlikely that any major changes in the extent of breeding habitat have occurred in the Arctic, though long-term changes resulting from climate change are likely to negatively affect red knots (COSEWIC 2007, p. 16)

### **Risk of Small Population Size**

Genetic studies indicate that small populations are especially vulnerable to the accumulation of harmful genetic mutations (genetic drift), and that “effective population sizes” are significantly smaller than “census population sizes.” Not all individuals in a population contribute to the gene pool. Owing to the low genetic variability of wading bird species, concern has been expressed regarding the long-term genetic consequences of populations falling below 15,000 individuals (International Wader Study Group 2003, p. 11). Based on

what is known of red knot populations at this time (e.g., winter counts and counts in spring migration areas), red knots have continued to decline and are approaching a level where the risk of small population size is of increasing concern. The relationship between birds occupying different wintering areas and their distribution within breeding areas is not fully known. If birds from the 3 known major wintering areas (e.g. Tierra del Fuego, Maranhão, and Florida/southeastern US) are found to represent distinct subpopulations occupying differing breeding areas, the risk of genetic fitness consequences from small population size will be greater, having arrived at the level of concern for shorebirds with low genetic variability. Genetic drift problems that rise to the level of threatening the persistence of a species tend to occur only with extremely small populations. Therefore, we do not believe there is a risk of harmful genetic mutation that threatens the persistence of the red knot at this time.

## **Conservation Measures Planned or Implemented :**

In response to concern for impacts to the red knot and other migratory shorebirds, the ASMFC adopted a Fishery Management Plan for the Horseshoe Crab in 1998. Beginning in 1999, the ASMFC imposed reduced State quotas for horseshoe crabs harvested for the bait industry. Since that time, the ASMFC has further restricted horseshoe crab harvest to increase the availability of horseshoe crab eggs in Delaware Bay for migratory shorebird populations. From 2004 to 2008, annual landings of horseshoe crabs have been reduced by over 70 percent from the reference period landings of the mid to late 1990's (ASMFC 2008, p. 2; 2009b, p. 40). In 2008, New Jersey enacted legislation imposing a moratorium on horseshoe crab harvest until such time as red knot populations recover. See the discussion above concerning regulatory mechanisms (Factor D) for a description of restrictions on horseshoe crab harvest.

In 2000, ASMFC recommended that NMFS implement a 30 nautical mile radius horseshoe crab harvest closure (including for biomedical use) off the mouth of Delaware. In March 2001, the NMFS established the Carl N. Shuster, Jr. Horseshoe Crab Reserve, an area of nearly 1,500 square miles closed to horseshoe crab harvest in federal waters off the mouth of Delaware Bay.

In 2009, an ARM workgroup, comprised of members of the ASMFC Horseshoe Crab and USFWS Shorebird Technical Committees, completed development of an adaptive resource management framework that takes a structured decision making and adaptive management approach to horseshoe crab harvest management constrained by red knot conservation. The linked population models for horseshoe crabs and red knots in the Delaware Bay predict the consequences of the alternative harvest levels on both horseshoe crabs and red knots. Application of the ARM framework results in an optimization table that recommends harvest policy for all possible combinations of population levels. The policy recommendations take into account ecological and environmental uncertainty (ASMFC 2009a, pp. 2-39). Adoption of the ARM framework is one of several horseshoe management options under review in 2011 by the ASMFC. See discussion above concerning modification of habitat through reduced forage base in Delaware Bay (Factor A).

Starting in 2003, major sections of the New Jersey shoreline of the Delaware Bay have been closed to human use during the peak of the stopover at the initiative of the New Jersey Division of Fish and Wildlife in order to reduce disturbance to shorebirds by people and dogs.

In May 2006, a key land parcel within Mispillion Harbor, Kent County, Delaware was purchased for protection of red knots and other shorebirds by The Conservation Fund, based in Arlington, Virginia with a Mid-Atlantic office in Wilmington, Delaware. This parcel, spanning approximately 1 mile of shoreline at Mispillion Harbor, provides prime horseshoe crab spawning / red knot foraging habitat during the annual spring migratory stopover (K. Kalasz pers. comm. 2006).

As a result of the red knot's decline, in November 2005, the parties to the Bonn Convention (which includes Argentina and Chile, but not the United States, Brazil, or Canada) determined that *C. c. rufa* was endangered. As such, the red knot was added to Appendix 1 of the Convention which commits the parties to strive toward

protection of the species and the conservation of its habitat.

In April 2007 the Canadian government's Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated *C. c. rufa* as endangered. The COSEWIC was established as an independent body of experts responsible for identifying and assessing species considered to be at risk. Species that have been designated by COSEWIC may then qualify for legal protection and recovery under Canada's Species at Risk Act.

In November 2009, the National Fish and Wildlife Foundation (NFWF) and the Manomet Center for Conservation Sciences, Shorebird Recovery Project hosted the first International Red Knot Working Group meeting held at St. Catherine's Island, Georgia. The purposes of the meeting were to form an ongoing Red Knot Working Group and to assist the NFWF in creating a logic model to inform development of a "business plan" for the recovery of the *rufa* subspecies of red knot. The meeting was the first time that key shorebird biologists and others actively engaged in red knot conservation from throughout the species range were able to meet as a group to discuss threats and conservation needs for the species. Representatives were present from Canada (Ontario and Quebec), the United States (Massachusetts, New Jersey, Delaware, Virginia, South Carolina, Georgia, Florida, and Texas), Uruguay, Brazil, Argentina, and Chile. A draft of the NFWF red knot business plan was prepared in March 2010 and is undergoing review by Red Knot Working Group.

The red knot is included as a species of conservation concern in wildlife action plans in the following states: Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Texas, and Virginia. State wildlife action plans outline steps needed to conserve wildlife and habitat. Taken as a whole, they present a national action agenda for preventing wildlife from becoming endangered. States with documented occurrence of red knot that did not include the species in state wildlife action plans include Connecticut and New Hampshire.

## **Summary of Threats :**

Although small in relation to the taxon's entire range, the habitat at Delaware Bay plays a crucial role in the persistence of the *rufa* subspecies of the red knot. A large proportion of migrating red knots use the Delaware Bay as a staging area on their northward migration in the spring. The abundance and availability of horseshoe crab eggs in the intertidal foraging habitat used by red knots in Delaware Bay is key to building fat reserves considered crucial for sustaining red knots on their migration from the Delaware Bay and for survival and successful reproduction on arctic breeding grounds. A major threat to the *rufa* subspecies of the red knot is the past, present, and threatened destruction, modification, and curtailment of its habitat through the reduction in horseshoe crabs, and thus the abundance of horseshoe crab eggs at the principal migratory stopover area in the Delaware Bay of Delaware and New Jersey. Erosion related to rising sea levels, and shoreline stabilization, also is contributing to the threat of destruction and modification of intertidal foraging habitat in the Delaware Bay. Although erosion and shoreline stabilization projects also are impacting habitat used by migrating knots elsewhere along the Atlantic Coast, we lack sufficient information on the scope and scale of habitat destruction and modification for migrating red knots, and the impacts to the species, for areas other than the Delaware Bay.

Recent changes in regulations pertaining to limits on commercial harvest of horseshoe crab may help stabilize or restore the crab population and the availability of eggs as a food source for the red knot in the long-term. However significant benefits of these management actions will not be realized immediately. As the horseshoe crab is relatively long-lived and slow to mature, reaching breeding age at about 10 years of age, there would likely be at least a 10-year lag time between fishery restrictions and the full effect of changes in horseshoe crab populations. To date, existing regulatory mechanisms have been inadequate to ensure horseshoe crab populations are at levels sufficient to consistently produce the abundance of horseshoe crab eggs that are essential to build up fat reserves considered crucial for sustaining red knots on their nonstop flight from the Delaware Bay and for survival and successful reproduction on arctic breeding

grounds. Information for 2009 indicates that a high proportion of red knots at the Delaware Bay stopover found sufficient horseshoe crab eggs for birds to attain threshold weight gains, leaving the Bay in good condition, but it remains to be seen if this will be a long-term trend. Existing regulatory mechanisms also have not been adequate to address the destruction and modification of intertidal foraging habitat due to erosion and shoreline stabilization involving the Delaware Bay area.

A die-off of a substantial number of red knots from undetermined causes, as occurred in 2007 during migration, poses a significant threat to the red knot. However, it is not known if this is an isolated incident or is likely to recur.

The impacts of competition from gulls and human disturbance to red knots within foraging and roosting habitats are unclear. They may be contributing to reduced fitness of individual red knots, but we do not know whether such impacts are occurring at sufficient levels to pose a threat to the persistence of the subspecies. We note also that some measures have been taken to reduce human disturbance in the New Jersey portions of the Delaware Bay.

Disease and predation do not appear to pose threats to the persistence of the red knot.

Impacts to wintering red knots in South America include past and potential habitat destruction and modification due to oil spills at wintering concentration areas, hunting, exposures to epizootic disease, and parasitic infestations. We do not have sufficient information on the size and scope of any of these ongoing or potential impacts in the South American wintering areas to conclude that they pose a threat to the entire subspecies.

In summary, based on our assessment of the life history and status of the red knot, we conclude that the present and threatened destruction and modification of habitat, particularly in the Delaware Bay, and the inadequacy of existing regulatory mechanisms related to habitat destruction and modification, pose significant risks to the *rufa* subspecies of the red knot. Therefore, we conclude that the best available information on biological vulnerability and threats supports a proposal to list the *rufa* subspecies of the red knot (*Calidris canutus rufa*) under the ESA. Although listing this subspecies is warranted, preparation and publication of a proposal is precluded by higher-priority listing actions. Thus, the red knot meets our definition of a species that is a candidate for listing.

The Service finds that this taxon is warranted for listing throughout all its range, and, therefore, finds that it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range.

#### **For species that are being removed from candidate status:**

\_\_\_\_\_ Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions(PECE)?

#### **Recommended Conservation Measures :**

Recommended conservation measures include: Continue monitoring of Delaware Bay migratory and South American wintering populations; increase the availability of the horseshoe crab egg forage base by protecting horseshoe crab populations; and protect and enhance foraging and roosting habitat on the Delaware Bay and other Atlantic coastal sites. Although there is uncertainty as to risks posed by human disturbance and competition from gulls, we recommend developing management solutions to decrease competition from gulls and reduce human disturbance at roosting and foraging sites. In addition, we also recommend identifying all important breeding locations and develop conservation strategies to protect key sites; developing a system for determining yearly population demographic status based on survey results, capture data, and resightings of

banded individuals; and developing and implementing conservation plans for protection of key non-breeding habitats within North, Central, and South America.

## Priority Table

Magnitude	Immediacy	Taxonmomy	Priority
<b>High</b>	<b>Imminent</b>	Monotypic genus	1
		Species	2
		<b>Subspecies/Population</b>	<b>3</b>
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/Population	6
Moderate to Low	Imminent	Monotype genus	7
		Species	8
		Subspecies/Population	9
	Non-Imminent	Monotype genus	10
		Species	11
		Subspecies/Population	12

### Rationale for Change in Listing Priority Number:

#### Magnitude:

Harvest of horseshoe crabs at the principal migration stopover site within the Delaware Bay has significantly diminished the availability of horseshoe crab eggs that are the food resource critical for the red knots to rebuild fat reserves needed to continue their migration to Arctic breeding areas. A high proportion of red knots leaving the Delaware Bay fail to reach the threshold departure masses that are considered crucial to adult survivorship and reproductive success. The issue of availability of horseshoe crab eggs, the main food resource for red knots in the Delaware Bay, has not been resolved. Recent and on-going efforts to reduce commercial harvest of horseshoe crabs may result in increased availability of eggs for migrating red knots, but the effects of the reduction in horseshoe crab will not be immediate, as it could take another decade before numbers of spawning horseshoe crabs rebound to the point that red knots can make the necessary weight gain in all years, especially those crucial bad weather years. Habitat loss due to erosion and shoreline protection practices also pose risks. The red knot population within the principal wintering areas in Chile and Argentina declined by approximately 85 percent from 1985 to 2011. Based on consideration of all of the available information we consider the magnitude of the threat to be high at this time.

#### Imminence :

The reduction of horseshoe crab food resources on the Delaware Bay has been ongoing since the mid-1990s, and increasingly restrictive quotas or harvesting bans have been implemented since 1999. We expect it will take a few years for the food resource to recover, due to the slow maturity of horseshoe crabs. Despite additional harvest regulations by the ASMFC and member States, numbers of spawning female horseshoe crabs have not yet shown a long-term increase and suppressed forage conditions for red knot persist within the Delaware Bay stopover. The combined effect of reduced numbers of spawning horseshoe crabs, reduced foraging and spawning habitat from ongoing shoreline erosion, and periodic inclement weather events within

the Delaware Bay have resulted in a long-term trend of red knots leaving Delaware Bay below the threshold weight of 180 g. Birds must achieve threshold weight not only to fuel migration to the Arctic and to sustain the transformation from a physiological state needed for migration to one needed for successful breeding, but also for survival. Numbers of red knots observed in wintering areas remain well below historic numbers and the long-term trend shows a decline consistent with that predicted by extinction modeling completed in 2004. Consequently, overall we conclude that threats to red knot are imminent at this time.

Yes Have you promptly reviewed all of the information received regarding the species for the purpose of determination whether emergency listing is needed?

## **Emergency Listing Review**

No Is Emergency Listing Warranted?

Commercial horseshoe crab harvesting has been identified as a key factor in the decline of the red knot. Erosion of beach habitat and human disturbance also may be contributing to the decline. However, restrictions have been adopted on the harvest of horseshoe crabs in Delaware and a moratorium on harvest of horseshoe crabs has been enacted in New Jersey. Protective measures have been undertaken by New Jersey and Delaware to limit human access along Delaware Bay beaches to prevent disturbance to red knots and other shorebirds foraging on horseshoe crab eggs.

Although peak counts of red knots in the Delaware Bay have been well below historic numbers, they remained relatively constant over the five year period of 2004-2008 13,315 in 2004, 15,345 in 2005, 13,445 in 2006 (K. Clark pers. comm. 2006), 12,375 in 2007 (A. Dey pers. comm. 2007), and 15,395 in 2008 (Dey et al., 2008, p.1). Beginning in 2009, a new survey methodology was implemented for the Delaware Bay stopover area to include ground counts that more accurately reflect concentrations of red knots using Mispillion Harbor, Delaware and to include aerial surveys of red knots using Atlantic coastal marshes near Stone Harbor, New Jersey. The highest 2009 ground count of 27,187 red knots occurred on May 26 with the majority of red knots counted in Mispillion Harbor, only a few hundred elsewhere in Delaware, and 900 in New Jersey. Information for 2009 and 2010, indicate that a high proportion of red knots at the Delaware Bay stopover found sufficient horseshoe crab eggs for birds to attain threshold weight gains, leaving the Bay in good condition, but it remains to be seen if this will be a long-term trend. Surveys by the Canadian Wildlife Service of the principal South American wintering areas indicated that, although precariously low, wintering populations in 2005 through 2007 remained stable. Subsequent surveys by the Canadian Wildlife Service in 2008, showed that the South American red knot wintering population experienced a 15 percent decline in from 2007 to 2008. This decline is believed to be attributed to an April 2007 die-off of red knots occurring off the coast of Uruguay. While the exact cause of the shorebird die-off remains undetermined, it is thought to be from a red tide (harmful algal bloom) event. No further die-offs were reported in 2008 or 2009, indicating that this was likely an isolated incident. An increase in South American red knot numbers in 2009, back to population levels observed in 2005 to 2007, are indicative of a good breeding season in summer of 2008. Numbers of red knots overwintering in the Tierra del Fuego region of South American declined in the winter of 2011, but not all traditional wintering areas along the Patagonian coast were surveyed, so it is unknown if birds were wintering elsewhere. Overall, this information does not support emergency listing of the red knot at this time.

## **Description of Monitoring:**

Monitoring of the red knot will include review of current scientific literature and contacting species experts, and State and international resource agencies regarding red knot status and threats. These efforts will be on-going throughout the monitoring period and will occur as information becomes available.

**Indicate which State(s) (within the range of the species) provided information or comments on the**

**species or latest species assessment:**

Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Virginia

**Indicate which State(s) did not provide any information or comment:**

none

**State Coordination:**

The Service contracted the NJENSP to compile an initial status assessment for the red knot. A draft assessment provided to the Service underwent both internal and external peer review. The final assessment report was received by the Service in May 2007. In the course of preparing the assessment, the NJENSP contacted biologists within each State along the Atlantic coast of the United States. All States contributed information. The Service has contacted all States within the red knot range annually for additional information for subsequent updates to this assessment.

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## **Approval/Concurrence:**

Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

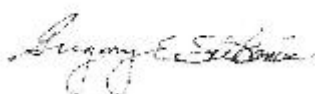
Approve:

  
Andrew D. Fitch, Northeast Region

06/03/2011

Date

Concur:



10/07/2011

Date



Did not concur: \_\_\_\_\_

\_\_\_\_\_  
Date

Director's Remarks: